

# AERONAUTICAL ENGINEERING

## A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 249)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in January 1990 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*



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# INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 525 reports, journal articles and other documents originally announced in January 1990 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA)*.

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the bibliography consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category.

Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cumulative index will be published.

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# TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED  
ON MICROFICHE

ACCESSION NUMBER → **N90-10834\*** # Old Dominion Univ., Norfolk, VA. Dept of Mechanical Engineering and Mechanics. ← CORPORATE SOURCE

TITLE → **AN EXPERIMENTAL INVESTIGATION OF THE AERODYNAMIC CHARACTERISTICS OF SLANTED BASE OGIVE CYLINDERS USING MAGNETIC SUSPENSION TECHNOLOGY**

AUTHORS → CHARLES W. ALCORN and COLIN BRITCHER Nov. 1988 ← PUBLICATION DATE

CONTRACT NUMBER → (Contract NAG1-716)

REPORT NUMBERS → (NASA-CR-181708; NAS 1.26:181708) Avail: NTIS HC A05/MF A01 ← AVAILABILITY SOURCE

COSATI CODE → CSCL 01/1 ← PRICE CODE

An experimental investigation is reported on slanted base ogive cylinders at zero incidence. The Mach number range is 0.05 to 0.3. All flow disturbances associated with wind tunnel supports are eliminated in this investigation by magnetically suspending the wind tunnel models. The sudden and drastic changes in the lift, pitching moment, and drag for a slight change in base slant angle are reported. Flow visualization with liquid crystals and oil is used to observe base flow patterns, which are responsible for the sudden changes in aerodynamic characteristics. Hysteretic effects in base flow pattern changes are present in this investigation and are reported. The effect of a wire support attachment on the 0 deg slanted base model is studied. Computational drag and transition location results using VSAERO and SANDRAG are presented and compared with experimental results. Base pressure measurements over the slanted bases are made with an onboard pressure transducer using remote data telemetry. Author

# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED  
ON MICROFICHE

ACCESSION NUMBER → **A90-13017\*** # Texas A&M Univ., College Station. ← CORPORATE SOURCE

TITLE → **IN-FLIGHT BOUNDARY-LAYER TRANSITION MEASUREMENTS ON A SWEEP WING**

AUTHORS → ANWAR AHMED (Texas A & M University, College Station), WILLIAM H. WENTZ (Wichita State University, KS), and R. NYENHUIS (Cessna Aircraft Co., Wichita, KS) ← AUTHORS' AFFILIATION

CONTRACT NUMBER → (Contract NAG1-104) Copyright ← JOURNAL TITLE

Flight tests were conducted at three different altitudes to detect transition on a smoothed test region of a swept-wing business jet wing using surface hot-film sensors and sublimating chemicals. Strong influence of sweep angle on transition location was observed when the aircraft was flown at some sideslip conditions to simulate changes in effective wing sweep angle. No effects of engine noise on transition were measured when different engine power settings were used. Flight instrumentation and ground data analysis techniques are described. Correlation was obtained between the hot-film sensor signals and sublimating chemicals for transition detection. Crossflow vortices were observed for one flight condition. Results of analyzed data for various flight-test conditions are presented. Author

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*A Continuing Bibliography (Suppl. 249)*

FEBRUARY 1990

01

## AERONAUTICS (GENERAL)

**A90-10170**

### **TARGET CLASSIFICATION BY VIBRATION SENSING**

WOLFGANG KRANZ (Siemens AG, Unterschleissheim, Federal Republic of Germany) IN: Infrared technology XIV; Proceedings of the Meeting, San Diego, CA, Aug. 15-17, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 383-387.

Copyright

A method which classifies targets by evaluating their vibration signatures is presented. The vibration spectra of different types of targets are measured by an experimental heterodyne laser radar. The measured signals show characteristic vibration signatures. The applications of the target classification, especially for helicopters, are discussed. The measured ranges in field tests were more than 10 km. If a target has a type characteristic vibration signature, the system can be used for noncooperative classification. R.B.

**A90-10624#**

### **APG-70 RADAR TEST PACKAGE DEVELOPMENT AID**

STEPHEN G. NOBIS (McDonnell Aircraft Co., Saint Louis, MO) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989. 5 p. refs

(AIAA PAPER 89-3044) Copyright

Considerable time and money is spent maintaining fighter aircraft. Techniques to reduce maintenance costs are needed. Artificial Intelligence techniques have been applied to the Depot Level Maintenance System for the APG-70 Radar in the McDonnell Douglas F-15E fighter aircraft. An expert system that assists in the design and development of the Test Program Set associated with each APG-70 Radar Module is examined. Author

**A90-12763**

### **SYSTEM IDENTIFICATION COLLABORATION - THE ROLE OF AGARD**

PETER HAMEL (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 207-212.

Copyright

The benefits of rotorcraft system identification are discussed as well as a requirement for multidisciplinary collaboration and the AGARD (Advisory Group for Aerospace Research and Development) working group FMP-WG 18. The objectives of the working group are to evaluate the strength and weakness of the different approaches and to develop guidelines for the application of identification techniques to be used more routinely in design and development. Another goal is to define an integrated and coordinated methodology for application of system identification based on the strengths of each method. K.K.

**N90-10001#** Office of Air Force History, Washington, DC.

### **ENCYCLOPEDIA OF US AIR FORCE AIRCRAFT AND MISSILE SYSTEMS. VOLUME 2: POST-WORLD WAR 2 BOMBERS, 1945-1973**

MARCELLE S. KNAACK 1988 618 p

(AD-A209273) Avail: NTIS HC A99/MF A01 CSCL 01/3

An overview is given of the basic development, technical and basic mission performance, and programs for the B-36 Peacemaker; B-45 Tornado; B-47 Stratojet; B-50 Superfortress; B-52 Stratofortress; B-57 Canberra; B-58 Hustler; B/RB-66 Destroyer; World War 2 bombers in the postwar period; and post-World War 2 experimental and prototype bombers. GRA

**N90-10002\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **A STUDY OF HIGH-LIFT AIRFOILS AT HIGH REYNOLDS NUMBERS IN THE LANGLEY LOW-TURBULENCE PRESSURE TUNNEL**

HARRY L. MORGAN, JR., JAMES C. FERRIS, and ROBERT J. MCGHEE Jul. 1987 64 p

(NASA-TM-89125; L-16266; NAS 1.15:89125) Avail: NTIS HC A04/MF A01 CSCL 01/1

An experimental study was conducted in the Langley Low Turbulence Pressure Tunnel to determine the effects of Reynolds number and Mach number on the two-dimensional aerodynamic performance of two supercritical type airfoils, one equipped with a conventional flap system and the other with an advanced high lift flap system. The conventional flap system consisted of a leading edge slat and a double slotted, trailing edge flap with a small chord vane and a large chord aft flap. The advanced flap system consisted of a leading edge slat and a double slotted, trailing edge flap with a large chord vane and a small chord aft flap. Both models were tested with all elements nested to form the cruise airfoil and with the leading edge slat and with a single or double slotted, trailing edge flap deflected to form the high lift airfoils. The experimental tests were conducted through a Reynolds number range from 2.8 to 20.9 x 1,000,000 and a Mach number range from 0.10 to 0.35. Lift and pitching moment data were obtained. Summaries of the test results obtained are presented and comparisons are made between the observed aerodynamic performance trends for both models. The results showing the effect of leading edge frost and glaze ice formation is given. Author

02

## AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

**A90-10074**

### **MARGINAL SEPARATION OF LAMINAR AXISYMMETRIC BOUNDARY LAYERS [MARGINALE ABLOESUNG LAMINARER ACHSENSYMMETRISCHER GRENZSCHICHTEN]**

A. KLUWICK (Wien, Technische Universitaet, Vienna, Austria) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN

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0342-068X), vol. 13, July-Aug. 1989, p. 254-259. In German. refs

Copyright

The interactions of axisymmetric, laminar, supersonic boundary layers have been studied in detail in recent years using triple-deck theory. The results indicate that the uniqueness of the solutions is lost over a certain range of the relevant parameters. It is shown here that multiple solutions occur when the pressure disturbances initiating the interactions extend over a scale whose length is large compared to the triple-deck scale. C.D.

### A90-10137#

#### **NATURAL LAMINAR FLOW RESEARCH FOR SUBSONIC TRANSPORT AIRCRAFT IN THE FRG**

H. KOERNER (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) ICAS, International Congress of the Aeronautical Sciences, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Paper. 14 p. refs

Different measuring techniques used for the detection of transition laminar/turbulent characteristics of natural laminar flow and other boundary-layer parameters are described, together with the results obtained. Numerical methods for the prediction of the stability of laminar boundary layer are developed, and the predictions are compared with experimental results. I.S.

### A90-10224

#### **OSCILLATING THIN WINGS IN INVISCID INCOMPRESSIBLE FLOW**

N. SINGH, S. AIKAT, and B. C. BASU (Indian Institute of Technology, Kharagpur, India) Aeronautical Journal (ISSN 0001-9240), vol. 93, Aug.-Sept. 1989, p. 272-277. Research supported by the Aeronautical Research and Development Board of India. refs

Copyright

A method has been developed for calculating the load distribution, overall forces and moments on a thin wing of arbitrary shape undergoing small amplitude simple harmonic motion in inviscid, incompressible flow. The method is compared with experimental data and other theoretical methods for wings and control surfaces in pitching oscillation and wings going through a sinusoidal vertical gust. Author

### A90-10228#

#### **NUMERICAL ANALYSIS OF FLOW OF AN IDEAL FLUID PAST AN AIRFOIL [NUMERYCZNA ANALIZA OPLYWU PROFILU LOTNICZEGO PLYNEM DOSKONALYM]**

WIENCZYSLAW STALEWSKI Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 112-113, 1988, p. 61-74. In Polish. refs

A numerical method for determining flow of an ideal fluid past an airfoil is presented. It belongs to a class referred to as panel methods, in which the flow potential is induced by a set of singularities arranged along the boundary of the airfoil. Owing to the particular way in which the singularities are arranged, the method differs from other methods by being more convenient and more accurate. Another advantage is that there are no limitations on the geometry of the airfoil and the number of its elements. This enables the method to be used for the study of problems of high-lift devices (the design and optimization of airfoils with flaps, flap-ailerons or slots) and for the determination of an airflow past an airfoil in the neighborhood of the earth and in the space between walls. The method has been tested for a few airfoils selected from a catalog. The results have been compared with those of theoretical solutions and experimental investigations. Author

### A90-10340#

#### **THE NUMERICAL METHOD FOR SOLVING THE HIGH REYNOLDS HYPERSONIC VISCOUS SHOCK LAYER**

ZHIMING LIU and QIFEN WU (National University of Defence Technology, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, Sept. 1989, p. 291-297. In Chinese, with abstract in English. refs

In the present paper a mesh stretching transformation is introduced into the numerical integrating method for the hypersonic

viscous shock layer presented by Hosny. The present method is a little advanced than the Hosny (1978) method in that it can solve the hypersonic viscous shock layer flow field for higher Reynolds number and it can march further along the slender blunt bodies. The numerical results obtained here compare well with the experimental results of Little (1969). Author

### A90-10346#

#### **THE WATER TUNNEL TEST OF DELAYING VORTEX BREAKDOWN OVER A DELTA WING USING SUPPLEMENTS**

JIAZHENG PAN (Nanjing Aeronautical Institute, People's Republic of China), JIADA MO, and J. M. WU (Tennessee, University, Knoxville) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, Sept. 1989, p. 344-350. In Chinese, with abstract in English. refs

A flat delta wing with a sharp leading edge and back-swept angle of 60 deg was tested in water tunnel. The leading edge vortex breakdown can be delayed using supplements to change the flow field over the upper surface of the wing. The flow visualization shows that the effects of the delay of vortex breakdown can be enhanced if an arc or a triangular guiding object is placed on an appropriate position of the upper surface, or if a small supplemental delta wing is placed over the wing surface. Author

### A90-10350#

#### **AN IMPROVED VERSION OF LTRAN2**

BEI LI and ZIQIANG ZHU (Beijing University of Aeronautics and Astronautics, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, Sept. 1989, p. 377-382. In Chinese, with abstract in English. refs

In the present study, an improved version of LTRAN2, which is named by BTRAN2, has been employed to predict unsteady aerodynamic loads even in high frequency. The ability to treat unsteady motions of all frequencies is obtained by solving the complete unsteady TSD equation. Solutions are advanced through series of time levels using ADI algorithm, in which the monotone differencing of Engquist and Osher is incorporated. The two-dimensional steady TSD equation is also solved by the AF2 scheme with the monotone differencing as an initial condition for solving the unsteady equation. Two examples have been calculated. Good agreements of the present method with the Euler solution and the available experimental data are obtained. Author

### A90-10641#

#### **THE EFFECT OF PITCH LOCATION ON DYNAMIC STALL**

E. J. JUMPER (USAF, Institute of Technology, Wright-Patterson AFB, OH), R. L. DIMMICK (USAF, Wright-Patterson AFB, OH), and A. J. S. ALLAIRE (Canadian Armed Forces, Canada) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 111, Sept. 1989, p. 256-262. refs

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Results of theoretical and wind-tunnel studies of the effect of pitch location on dynamic stall are reported for an airfoil pitching at constant rate. The effect of pitch location and rate on the delay in quarter-chord separation was predicted using a modified momentum-integral method; the wind-tunnel study involved the collection of time-varying pressure readings from 16 locations on an NACA 0015 airfoil that were subsequently used to determine lift, pressure-drag, and moment coefficients as functions of angle of attack for 140 test cases. It is found that the effect of the pitch location on dynamic stall is clearly evident and that the pitch-location dynamic-stall effects can be inferred from the theoretical prediction of the effect on delay in dynamic quarter-chord separation. V.L.

### A90-10699

#### **TURBULENCE MEASUREMENTS IN A FLOW GENERATED BY THE COLLISION OF RADIALLY FLOWING WALL JETS**

B. GILBERT (Grumman Research Center, Bethpage, NY) Experiments in Fluids (ISSN 0723-4864), vol. 7, no. 2, 1989, p. 103-110. refs

(Contract F49620-85-C-0111)

Copyright

Early results of an experimental investigation of the abnormally high turbulence level and mixing layer growth rate characteristics found in the upwash regions of aircraft with vertical short takeoff and landing (V/STOL) flows in ground effect are presented. The upwash flow is formed from the collision of two opposing radially flowing wall jets. The wall jets are created in a unique way that allows the upwash to form without any interference due to the source jets. The objective of this work is to systematically characterize the development and structure of the flow. The upwash flow exhibits very large mixing rates compared to turbulent free or wall jet flows. A unique set of two component velocity profiles was taken in the upwash flow field. These measurements include several higher moment terms that appear in the turbulent kinetic energy equations, as well as length scales and intermittency determinations. Measurements were taken along the axis connecting the two source jets as well as off this axis at six measurement stations above ground. The results provide detailed data on an important class of flows where none existed, and they are expected to significantly improve the computational empirical tools available for predicting V/STOL behavior near the ground.

Author

A90-10938

**A STUDY OF THREE-DIMENSIONAL SUPERSONIC FLOW OF A REAL GAS PAST AXISYMMETRIC BODIES [ISSLEDOVANIYE PROSTRANSTVENNOGO SVERKHZVUKOVOGO OBTEKANIIA OSESIMETRICHNYKH TEL REAL'NYM GAZOM]**

V. R. DUSHIN, I. V. MININ, O. V. MININ, A. I. SELEZNEV, N. N. SMIRNOV et al. Moskovskii Universitet, Vestnik, Seriya 1 - Matematika, Mekhanika (ISSN 0579-9368), July-Aug. 1989, p. 41-49. In Russian.

Copyright

A method is proposed for the numerical integration of nonstationary three-dimensional equations of nonviscous gas dynamics for two-parameter media. The approach used here, which is based on a fully conservative first-order difference scheme, provides a way to investigate three-dimensional supersonic flow of a real gas past axisymmetric bodies over a wide range of incoming flow parameters. The efficiency of the software pack implementing this method is demonstrated by examples. V.L.

A90-11003#

**METHOD FOR CALCULATING THE UNSTEADY FLOW OF AN ELLIPTICAL CIRCULATION-CONTROL AIRFOIL**

MAO SUN and WEI WANG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 907-913. refs

Copyright

A numerical method is developed to study the unsteady aerodynamics of an elliptical airfoil in two-dimensional incompressible flow. In this method, it is assumed that the separation positions of the wall jet on the upper surface and the boundary layer on the lower surface of the airfoil can be determined by solving the quasi-steady boundary-layer equations; the discrete vortex model is used to model the wake, and the potential flow is calculated by conformal mapping technique. Results are presented and discussed for a number of cases that illustrate relevant characteristics of the unsteady flow of circulation-control airfoils.

Author

A90-11010#

**CANARD-WING INTERACTION IN UNSTEADY SUPERSONIC FLOW**

VALTER J. E. STARK (Saab-Scania, AB, Linköping, Sweden) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 951, 952. refs

Copyright

A simple method is presented for approximating unsteady aerodynamic forces on a canard configuration in unsteady supersonic flow. This method, developed in the 1960s, was used on the first canard military aircraft, SAAB 37 Viggen. It uses the

so-called CHB program, which is based on the source superposition principle. This paper compares the results obtained with this approximate method on a wing configuration consisting of four trapezoidal wing panels with results obtained from new general-configuration programs. I.S.

A90-11141#

**HYDRODYNAMIC VISUALIZATION OF THE FLOW AROUND A HIGH-SPEED AIRCRAFT PROPELLER**

H. WERLE (International Symposium on Flow Visualization, 5th, Prague, Czechoslovakia, Aug. 21-25, 1989) ONERA, TP no. 1989-108, 1989, 8 p.

(ONERA, TP NO. 1989-108)

Liquid- and gas-tracer visualizations have been successfully used in the various water tunnels of ONERA to study the particularly complex case of unsteady flows around a propfan. Different configurations have been analyzed this way: single four- and eight-blade rotors and a double rotor with 2 x 8 blades. The visualizations reveal the structure and size of the separation over the blades, and of the resulting tip vortices, as well as their variation as a function of the advance ratio and the Reynolds number. It was also possible, in each case, to delimit the various operating domains of the rotor tractor propeller, zero-traction, and braking.

Author

A90-11147#

**CALCULATION OF THREE-DIMENSIONAL TURBULENT FLOW IN A LINEAR TURBINE CASCADE [CALCUL DE L'ÉCOULEMENT TRIDIMENSIONNEL TURBULENT DANS UN AUBAGE RECTILIGNE DE TURBINE]**

L. CAMBIER and B. ESCANDE (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Meeting, 74th, Luxembourg, Aug. 28-Sept. 1, 1989) ONERA, TP no. 1989-115, 1989, 14 p. In French. Research supported by DRET. refs

(ONERA, TP NO. 1989-115)

The paper deals with the numerical simulation of a three-dimensional turbulent flow in a linear turbine cascade, by solution of the Reynolds-averaged compressible Navier-Stokes equations with an algebraic turbulence model. The numerical method is characterized by an explicit centered finite-difference scheme, associated with a multigrid convergence acceleration. The splitting of the computational domain in an O-type subdomain around the blade and two H-type subdomains upstream and downstream allows an accurate description of the round leading edges and trailing edges, while setting the upstream and downstream boundaries of the domain sufficiently far from the blade. The results obtained in a mesh containing more than 300,000 points (in a domain bounded by a symmetry plane) show complex phenomena of secondary flows, qualitatively similar to the phenomena observed in an experiment carried out at a lower flow velocity.

Author

A90-11148#

**UNSTEADY VISCOUS CALCULATION OF CASCADE FLOWS WITH LEADING-EDGE-INDUCED SEPARATION [CALCUL INSTATIONNAIRE EN FLUIDE VISQUEUX DES GRILLES D'AUBES A DECOLLEMENTS INDUITS PAR LES BORDS D'ATTAQUE]**

M. GAZAIX, P. GIRODROUX-LAVIGNE, and J. C. LE BALLEUR (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Meeting, 74th, Luxembourg, Aug. 28-Sept. 1, 1989) ONERA, TP no. 1989-116, 1989, 13 p. In French. Research supported by SNECMA. refs

(ONERA, TP NO. 1989-116)

A defect formulation approach is used to solve thin-layer integral viscous equations in order to investigate unsteady flows over airfoils and cascades where the flow separation or stall is induced by sharp leading edges. The method includes two transport equations for turbulence, and it employs a temporally consistent semiimplicit coupling method. Steady and unsteady results for the leading-edge separation over a sharp flat plate at incidence and over isolated compressor blades have been compared with experimental findings. A numerical method for internal flows which includes conditions

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of periodicity in space for steady flows and conditions of periodicity in space-time for unsteady flows is used to study separated flows in a cascade configuration. R.R.

**A90-11149#**

**NUMERICAL SIMULATION OF THREE-DIMENSIONAL UNSTEADY FLOWS IN TURBOMACHINES [SIMULATION NUMERIQUE DES ECOULEMENTS TRIDIMENSIONNELS ET INSTATIONNAIRES DANS LES TURBOMACHINES]**

ANTOINE FOURMAUX, GILLES BILLONNET, ALAIN LE MEUR, and ALAIN LESAIN (ONERA, Chatillon-sous-Bagneux, France) (NATO, AGARD, Colloque sur les Phenomenes d'Aerodynamique Instationnaire dans les Turbomachines, Luxembourg, Sept. 4-6, 1989) ONERA, TP no. 1989-118, 1989, 12 p. In French. refs (ONERA, TP NO. 1989-118)

For the aerodynamic study of turbomachinery, the numerical flow simulation takes a larger and larger place. These viscous and compressible fluid flows are three-dimensional and unsteady, so they are governed by the full Navier-Stokes equations. Nevertheless, the use of numerical methods to solve these equations is limited at the present time, and only applications of Euler methods are presented in this paper. After a short description of the physical phenomena and of the numerical method used, the conditions on the calculation domain boundaries are described. The simplifying assumptions which allow the complete stage computation are emphasized. The examples presented concern unsteady flow simulations in a turbine stage and in a supersonic nozzle. Author

**A90-11158#**

**INFLUENCE OF THE CONTROL LAW ON THE PERFORMANCE OF A HELICOPTER MODEL ROTOR**

A. DESOPPER, P. LAFON, and P. CERONI (ONERA, Chatillon-sous-Bagneux, France) (European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989) ONERA, TP no. 1989-136, 1989, 15 p. refs (ONERA, TP NO. 1989-136)

A model rotor test rig has been used for several years at the ONERA S2 Chalais-Meudon wind tunnel to study the local performance of helicopter rotors and the local flow on different blade tip shapes. Contrarily to previous tests performed with a free flapping rotor without any cyclic pitch control, in 1987, the rig was equipped with a cyclic pitch device and tested for three control laws. Total performance results obtained with a three-bladed rotor equipped with rectangular and parabolic sweptback tips, blade loads and test envelope, blade tip shapes effect and local flows on the blade are described. The tests are performed for a given rotating tip Mach number and each configuration is obtained for given total lift, total propulsive force, and advance ratio. Results show that the control law can be an important parameter in the performance of a helicopter rotor, in particular for the local flows over the blade. C.E.

**A90-11175#**

**AN IMPROVED METHOD FOR THE COMPUTATION OF UNSTEADY TRANSONIC POTENTIAL FLOW - APPLICATION FOR AIRFOIL AND BLADE PERFORMANCE PREDICTION**

H. BEZARD and M. COSTES (ONERA, Chatillon-sous-Bagneux, France) (European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989) ONERA, TP no. 1989-154, 1989, 18 p. refs (ONERA, TP NO. 1989-154)

A finite difference code solving the unsteady full potential equation for both two-dimensional and three-dimensional flows has been improved by introducing a C-grid topology. The results are compared to previous calculations performed with an H-grid. An effort to calculate the airfoils and blades inviscid drag has been undertaken. The different ways to estimate the unsteady inviscid drag (pressure drag, wave drag) are discussed, and the method is applied to airfoils and blades performance evaluation. Author

**A90-11434**

**THREE-DIMENSIONAL MODELING OF TURBULENT TRANSONIC FLOW AT THE EXIT OF A TWIN ENGINE [MODELISATION TRIDIMENSIONNELLE DE L'ECOULEMENT TRANSSONIQUE TURBULENT EN SORTIE D'UN BIREACTEUR]**

LAURENT LEQUETTE, PIERRE SAGNES, and ELIE ZNATY (Bertin et Cie., Plaisir, France) AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 26 p. In French.

(AAAF PAPER NT 88-16) Copyright

The three-dimensional CALIFE code was used to model the unsteady turbulent transonic flow at the exit of a Rafale-type twin engine. The CALIFE code takes into account the expansion rate of the turbojet, the turbulent mixing of the various constituents, the mixing between the cold and hot fluxes in the nozzle, and the interaction between the reactor jets and the external flow. The determination of the location of the pressure minimum allows the location of the recompression shock zone to be obtained. The maximum Mach number of 1.7 achieved corresponds to the value of the pressure minimum prior to the recompression shock. Results are presented for the velocity field and for the mass fraction of the combustion gas. R.R.

**A90-11435**

**THE INCLUSION OF A SIMILARITY REPRESENTATION OF COMPRESSOR ROTATION IN THE MODELING OF THE INTERACTION OF CANNON FIRING WITH AIR INTAKES AT INCIDENCE [INTERACTION DU TIR CANON ET D'UNE PRISE D'AIR EN INCIDENCE AVEC SIMILITUDE DE ROTATION DU COMPRESSEUR]**

J. M. DESSE (ONERA, Chatillon-sous-Bagneux; Lille I, Universite, Villeneuve-d'Ascq, France) AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 40 p. In French. refs

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A previous simulation of the effects of arms firing on the functioning of air intakes at incidence has been modified by the inclusion of a similarity representation of a compressor rotor with reduced frequency. The nozzle is replaced by a helix of inclined blades which is driven by a turbine. Measurements of steady and unsteady pressure obtained inside air intakes with or without blades demonstrate that it is not necessary to include similarity representations of compressor rotation in simulations performed to determine internal distortion. Compressor rotation effects only occur locally. The present results are also found to be valid for the case of firing intensities which are reduced by the presence of a decompressor. R.R.

**A90-11436**

**WIND-TUNNEL TEST OF THE AIR INTAKE OF AN UNDUCTED FAN [ESSAI EN SOUFFLERIE DE L'ENTREE D'AIR D'UN TURBOREACTEUR A HELICES RAPIDES]**

H. JOUBERT, P. FESSOU (SNECMA, Centre de Villaroche, Moissy-Cramayel, France), J. C. RAYNAL, and F. GARCON (ONERA, Chatillon-sous-Bagneux, France) AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 41 p. In French.

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The flow around the nacelle and the distortion in the air intake of the THR-GE36 engine were characterized at low velocity in the F1 wind tunnel. The results demonstrate that the separation boundary of the air intake occurs at large incidence and sideslip angles that are not encountered in flight, and that distortion levels are moderate in the presence of a cross wind, even with boundary layer separation. In the steady regime, separation does not occur on the nacelle, even for the case of an extremely low air flow in the air inlet, and the pylon wake is moderated in size and amplitude. High-velocity tests performed in the S1 wind tunnel permitted drag measurement of the nacelle/pylon configuration to be obtained for Mach numbers corresponding to cruise conditions. R.R.

A90-11597

**A CLASS OF IMPLICIT UPWIND SCHEMES FOR EULER SIMULATIONS WITH UNSTRUCTURED MESHES**

L. FEZOU (Institut National de Recherche en Informatique et en Automatique, Valbonne, France) and B. STOUFFLET (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) *Journal of Computational Physics* (ISSN 0021-9991), vol. 84, Sept. 1989, p. 174-206. refs

(Contract DRET-84-014)

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The upwind-type implicit FEM Euler-flow simulation scheme of Angrand et al. (1983, 1984, and 1985) is extended and refined, with a focus on techniques for building up an approximation scheme on an unstructured or distorted grid. The mathematical basis of the method is given in detail, and results for steady channel flow, steady flow around a NACA0012 airfoil, and high-speed flow past a blunt body are presented in extensive graphs and characterized in detail. The first-order version of the scheme is found to have nearly quadratic convergence, and the second-order scheme is relatively efficient; both implicit methods are significantly more reliable than explicit techniques at high Mach numbers and angles of attack. It is also demonstrated that the use of relaxation to obtain the incomplete solution of the linear system is efficient and suitable for three-dimensional computations. T.K.

A90-11604

**ON UNSTEADY SURFACE FORCES, AND SOUND PRODUCED BY THE NORMAL CHOPPING OF A RECTILINEAR VORTEX**

M. S. HOWE (BBN Laboratories, Inc., Cambridge, MA) *Journal of Fluid Mechanics* (ISSN 0022-1120), vol. 206, Sept. 1989, p. 131-153. Research supported by the U.S. Navy. refs

Copyright

An investigation is made of the sound produced when a rectilinear vortex is cut at right angles to its axis by a nonlifting airfoil of symmetric section. The motions are at sufficiently low Mach number that the wavelength of the sound is large relative to the chord of the airfoil. In these circumstances the airfoil experiences no fluctuating lift during the interaction, and the radiation may be ascribed to an acoustic source of dipole type whose strength is equal to the unsteady drag. It is argued that previous analyses of the related problem of 'unsteady thickness noise' have ignored certain terms whose inclusion greatly reduces the predicted intensity of the radiation. A general formula for the surface forces is applied to deduce that the dipole strength is proportional to the square of the circulation of the vortex, and depends on the spanwise acceleration of the vortex induced by images in the airfoil. Numerical results are presented for typical airfoil sections, and a comparison is made with the unsteady lifting noise generated when the axis of the vortex is inclined at a small angle to the normal to the median plane of the airfoil. Author

A90-11610

**ON THE LENGTHSCALES OF LAMINAR SHOCK/BOUNDARY-LAYER INTERACTION**

EDGAR KATZER (DLR, Institut fuer theoretische Stromungsmechanik, Goettingen, Federal Republic of Germany) *Journal of Fluid Mechanics* (ISSN 0022-1120), vol. 206, Sept. 1989, p. 477-496. refs

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The interaction of an oblique shock with a laminar boundary layer on an adiabatic flat plate is analyzed by solving the Navier-Stokes equations numerically. Mach numbers range from 1.4 to 3.4 and Reynolds numbers range from 100,000 to 600,000. The numerical results agree well with experiments. The pressure distribution at the edge of the boundary layer is proposed as a sensitive indicator of the numerical resolution. Local and global properties of the interaction region are discussed. A comparison with the triple-deck theory shows that, for finite Reynolds numbers, the triple deck tends to overestimate the lengthscale substantially and that this discrepancy increases with increasing Mach number. Author

A90-11776

**UNSTEADY AERODYNAMICS AND AEROELASTICITY OF TURBOMACHINES AND PROPELLERS; PROCEEDINGS OF THE FOURTH INTERNATIONAL SYMPOSIUM, AACHEN, FEDERAL REPUBLIC OF GERMANY, SEPT. 6-10, 1987**

H. E. GALLUS, ED. and S. SERVATY, ED. (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) Symposium supported by DFG, MTU Motoren- und Turbinen-Union Muenchen GmbH, Kulite Semiconductor Products GmbH, et al. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, 791 p. For individual items see A90-11777 to A90-11808.

The present conference discusses topics in the theory of the unsteady aerodynamics of nonoscillating axial-flow cascades, the theoretical and experimental treatment of such cascades' blade-row interactions and uniform inlet flows, the theory of dynamic aeroelastic instabilities (flutter), and various turbomachine unsteady flow problems. Attention is given to the use of linearized Euler equations for the calculation of unsteady flows in turbomachinery, the role of acoustic resonances in unsteady turbomachine aerodynamics, unsteady flow visualization in a vibrating annular turbine cascade, the flutter characteristics of two-dimensional cascades in incompressible flow, acoustic resonance in centrifugal compressors, and self-excited oscillation of shock waves on an airfoil in two-dimensional transonic channel flow. O.C.

A90-11777#

**THE SOLUTION OF THE UNSTEADY TRANSONIC FLOW THROUGH A BLADE PASSAGE IN AN AXIAL TURBINE**

T. CHMIELNIAK, A. MISIEWICZ, and W. WROBLEWSKI (Slask, Politechnika, Gliwice, Poland) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 1-13. refs

A solution is presented for the unsteady, two-dimensional transonic flow through an axial turbine blade passage, where the flow is of a perfect, inviscid, and thermally nonconducting gas. Attention is given to the influence of periodic changes in the distribution of flow parameters at the inlet plane to the blade passage on blade-to-blade surface parameters. The solution is based on the 'finite volume' method associated with that of time-marching. Wake-cycle intensity is noted to be great in the initial portion of the passage, and to decrease subsequently. O.C.

A90-11778\*# United Technologies Research Center, East Hartford, CT.

**CALCULATION OF UNSTEADY EULER FLOWS IN TURBOMACHINERY USING THE LINEARIZED EULER EQUATIONS**

KENNETH C. HALL (United Technologies Research Center, East Hartford, CT) and EDWARD F. CRAWLEY (MIT, Cambridge, MA) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 15-38. Research supported by General Electric Co. and General Motors Corp. refs (Contract NSG-3079)

The model used by the present unsteady cascade flow calculation method is based on the linearized unsteady Euler equations and accounts for blade loading and geometry, shock motion, and wake motion. The steady flow that must be determined prior to the unsteady flow is ascertained by means of a Newton iteration procedure. A noteworthy feature of the procedure is the use of shock-fitting to determine steady and unsteady shock positions; the use of the Euler equations in conjunction with the Rankine-Hugoniot shock-jump conditions is found to directly model the generation of entropy and vorticity at shocks. Results are presented for both channel and cascade flows. O.C.

**A90-11779\*#** Notre Dame Univ., IN.

### **ANALYSIS OF NONUNIFORM SUBSONIC FLOWS ABOUT A ROW OF MOVING BLADES**

H. M. ATASSI (Notre Dame, University, IN) and J. R. SCOTT (NASA, Lewis Research Center, Cleveland, OH) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 39-67. refs  
(Contract NAG3-732)

The motion of a nonuniform flow about a row of moving blades is modeled as that of a three-dimensional rotational disturbance convected by the mean flow. The aerodynamic theories for such flows are reviewed for both linearly propagating disturbances and disturbances distorted by the mean flow. Linear theories results are examined to assess the effects of the gust variables, the Mach number, and the blade spacing, on the unsteady blade response. For loaded blades, the upstream disturbances are distorted by the blade mean flow. For a potential mean flow, the governing equations can be reduced to a single inhomogeneous nonconstant coefficient convective wave equation. A numerical procedure is developed using an elliptic grid system. The accuracy of the solutions strongly depends on the far-field radiation condition and the optimum determination of the grid system. Solutions are presently obtained for thick symmetric airfoils in three-dimensional gusts. Author

**A90-11780#**

### **ANALYSIS OF THE EFFECT OF ROTOR-ANGULAR-ACCELERATION ON THE FEATURES OF GAS FLOW IN TURBOMACHINERY**

X. L. WEI, L. X. HUANG, and S. Z. DUAN (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 69-85.

Inviscid three-dimensional equations are presented which govern the unsteady flow in a turbomachine with rotor angular acceleration, epsilon; attention is given to the unsteadiness of the flow field due to epsilon, as well as epsilon's effect on the unsteady flow field. This analytical treatment also examines the commonly employed quasi-steady assumption. It is established that epsilon has only a negligible effect on the fundamental characteristics of gas flow through turbomachinery. O.C.

**A90-11781#**

### **THE EFFECT OF THE MAGNITUDE OF THE INLET-BOUNDARY DISTURBANCE ON THE UNSTEADY FORCES ON AXIAL GAS-TURBINE BLADES**

THEODOSIOS P. KORAKIANITIS and DAVID GORDON WILSON (MIT, Cambridge, MA) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 109-124. Research supported by General Electric Co. refs

The unsteady forces generated by wake interaction and by potential-flow interaction from an upstream stator cascade on a downstream turbine-rotor cascade are computed using a two-dimensional, compressible, inviscid program. The wake interaction and the potential-flow interaction are inputs at the computational rotor-inlet boundary. The effect of variations of the magnitudes of these two interactions is investigated for stator-to-rotor-pitch ratio of 2.0. It is concluded that the dominant source of unsteadiness is the potential-flow interaction. Author

**A90-11782#**

### **UNSTEADY 2D FLOW CALCULATION IN TURBOMACHINERY CASCADES**

J. MYLONAS (Muenchen, Technische Universitaet, Munich, Federal

Republic of Germany) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 125-140. refs

The present, potential flow theory-based model for turbomachine cascade flow computation, under the assumption of a plane, unsteady, subsonic viscous flow, employs a vortex distribution feature in the modeling of blade surfaces, as well as a net of singularities around the profiles. The singularities' components are a source strength which simulates compressibility effects, and a vortex strength for unsteady viscous wake modeling. The unsteady wake vortices are noted to be shed in the trailing-edge region, near the separation points on both the suction and pressure sides of the blade airfoil profiles. O.C.

**A90-11783#**

### **MULTISTAGE COMPRESSOR VANE ROW AERODYNAMIC GUST RESPONSE**

VINCENT R. CAPECE and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 155-170. Research supported by USAF. refs

A series of experiments are performed to investigate and quantify the fundamental flow physics of multistage compressor vane rows at high reduced frequency values. Unique unsteady aerodynamic data are obtained and analyzed to define the effect of steady loading, aerodynamic forcing function waveform, vane row solidity, and potential flow interactions on the unsteady aerodynamics of each vane row of a three-stage axial flow research compressor. Author

**A90-11784#**

### **ROTOR-BLADES EXCITATION DUE TO DIFFERENTIAL INTERFERENCE OF VANE WAKES BETWEEN UPSTREAM STATOR-ROWS IN AN AXIAL COMPRESSOR**

NOBUYUKI YAMAGUCHI (Mitsubishi Heavy Industries, Ltd., Takasago, Japan) and HIROSHI KOBAYASHI (National Aerospace Laboratory, Tokyo, Japan) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 171-194.

Experiments conducted with a three-stage compressor have yielded results characterizing the aerodynamic rotor-blade excitation whose frequency is a function of the difference in the number of vanes between two upstream stator rows. On the basis of these results, and those of additional cascade tests and a simplified analysis, the origin of this blade excitation is identified to be the blade response to impinging vane wakes; the velocity defects of these impingements are selectively magnified by additional upstream stator wakes. The wakes most seriously affected were found to be equal in number to the difference between the vane numbers of the two stator rows. O.C.

**A90-11785#**

### **THE INFLUENCE OF THE WAKE STRUCTURE ON THE DYNAMIC BLADE LOAD**

Z. WIERCINSKI (Polska Akademia Nauk, Instytut Maszyn Przeplywowych, Gdansk, Poland) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 195-209. Research supported by the Alexander von Humboldt-Stiftung. refs

Experiments have been conducted to ascertain the influence of the vortex street in the wake of a single cylinder or a moving



cylinder row on the dynamic blade load of axial-flow turbomachines. In the case of influence exerted by the vortex street behind a single stationary cylinder, the energy of the power-spectrum peak in the pressure fluctuations of the blade surface at the blade frequency corresponding to the Strouhal frequency is found to depend on the mutual position of the cylinder and the blade in cascade, as well as on the position of the pressure-measurement point around the blade. The axial distance between the cylinder and the blade row is noted to powerfully influence the appearance of the vortex street behind the cylinder. O.C.

#### A90-11786#

##### UNSTEADY FLOW VISUALIZATION IN A VIBRATING ANNULAR TURBINE CASCADE OPERATING IN THE TRANSONIC FLOW REGIME

A. BOELCS, F. JOLLES, P. OTT, and D. SCHLAEFLI (Lausanne, Ecole Polytechnique Federale, Switzerland) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 229-243. Research supported by Brown Boveri et Cie AG.

A nonrotating annular cascade representative of contemporary gas turbine blading has been studied with unsteady shadowgraph flow-visualization while being driven in a controlled translational vibration mode at constant amplitudes and interblade phase angles, with a near-sonic outlet flow velocity that generated strong normal shock waves on the suction surface. A phase-reference signal from a blade displacement transducer was optically included in the flow visualization. Flow motion is found to be influenced by both the blade from which it emanates and the suction-side neighboring blade. O.C.

#### A90-11787#

##### EXPERIMENTAL INVESTIGATION OF THE TIME-DEPENDENT FLOW IN A VIBRATING ANNULAR CASCADE OPERATING IN THE TRANSONIC FLOW REGIME

A. BOELCS and D. SCHLAEFLI (Lausanne, Ecole Polytechnique Federale, Switzerland) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 245-269. Research supported by Brown Boveri et Cie AG. refs

An aeroelastic study has been conducted of a nonrotating annular cascade, in a variety of subsonic and transonic steady-state flow conditions, by obtaining time-dependent blade-surface pressure measurements while the blades are forced into translational vibration by electromagnetic exciters. The data are decomposed into influence coefficients indicative of the unsteady pressure which has been induced at the measured blade by a specific vibrating blade. The decomposition of coefficients indicates that unsteady perturbations cannot be tracked beyond two or three blade spacings, so that a linear cascade with seven or more blades will yield results similar to these for an annular cascade. O.C.

#### A90-11788#

##### A NUMERICAL METHOD SOLVING 2-D UNSTEADY FLOW FIELD AROUND CASCADE OF OSCILLATING AIRFOILS WITH ARBITRARY CAMBER AND THICKNESS

S. Z. DUAN, X. I. WEI, and S. ZHOU (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 271-291. refs

The present numerical method for obtaining the two-dimensional unsteady flow field around an oscillating airfoil cascade having arbitrary camber and thickness proceeds by solving the unsteady

small-disturbance potential equation to yield unsteady pressure distributions on the blades' surfaces. The method can be used to predict the onset of stall flutter in an actual compressor; good qualitative agreement has been thus obtained between experimental and numerical results. O.C.

A90-11789\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

##### THE UNSTEADY AERODYNAMICS OF AN OSCILLATING CASCADE IN A COMPRESSIBLE FLOW FIELD

DANIEL H. BUFFUM, DONALD R. BOLDMAN (NASA, Lewis Research Center, Cleveland, OH), and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 293-312. Previously announced in STAR as N88-13346. refs

Fundamental experiments were performed in the NASA Lewis Transonic Oscillating Cascade Facility to investigate and quantify the unsteady aerodynamics of a cascade of biconvex airfoils executing torsion-mode oscillations at realistic reduced frequencies. Flush-mounted, high-response miniature pressure transducers were used to measure the unsteady airfoil surface pressures. The pressures were measured for three interblade phase angles at two inlet Mach numbers, 0.65 and 0.80, and two incidence angles, 0 and 7 deg. The time-variant pressures were analyzed by means of discrete Fourier transform techniques, and these unique data were then compared with predictions from a linearized unsteady cascade model. The experimental results indicate that the interblade phase angle had a major effect on the chordwise distributions of the airfoil surface unsteady pressure, and that reduced frequency, incidence angle, and Mach number had a somewhat less significant effect. Author

#### A90-11790#

##### NUMERICAL INVESTIGATION OF UNSTEADY COMPRESSIBLE FLOW THROUGH NOZZLES AND CASCADES

A. BOELCS, T. H. FRANSSON (Lausanne, Ecole Polytechnique Federale, Switzerland), and M. F. PLATZER (U.S. Naval Postgraduate School, Monterey, CA) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 335-355. Research supported by Brown Boveri et Cie AG and U.S. National Research Council. refs

Numerical simulations have been conducted of fully unsteady compressible inviscid and rotational flow governed by Euler equations, in order to elucidate (1) subsonic flow through vibrating turbomachine cascades, where the blades are assumed to vibrate at a constant interblade phase angle that is implemented as a periodicity condition, and (2) transonic flow through a quasi-one-dimensional duct with oscillating backpressure. In the latter, the amplitude and frequency of the imposed backpressure are sufficient to either generate an oscillation of the shock around an average unsteady position (which need not be the steady-state position) or push the shock upstream through the subsonic part of the duct. O.C.

#### A90-11791#

##### COMPUTATION OF AERODYNAMIC BLADE LOADS DUE TO WAKE INFLUENCE AND AERODYNAMIC DAMPING OF TURBINE AND COMPRESSOR CASCADES

S. SERVATY, H. E. GALLUS, and H.-P. KAU (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 357-386. refs

## 02 AERODYNAMICS

A method for computing the two-dimensional, unsteady, subsonic flow through compressor and turbine cascades is presented. Aerodynamic blade loads due to wake influence of preceding blade rows and aerodynamic damping are considered as well. The nonlinear Euler-equations in conservative law form are solved by a combined method. For interior points of the time-dependent computation grid MacCormack's explicit predictor-corrector scheme is used. Boundary conditions are formulated by the method of bicharacteristics. Results for oscillating turbine cascades are compared with related experimental data and other numerical methods according to the Lausanne Aeroelasticity Workshop (Standard Configuration No. 4). First numerical examples of calculated aerodynamic blade loads due to incoming wakes are presented as well. Author

**A90-11792#**

### **NUMERICAL EULER SOLUTION FOR THE INTERACTION BETWEEN OSCILLATING CASCADE AND FORCED INLET UNSTEADINESS**

HE LI and ZHOU SHENG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 387-404. refs

Denton's (1982) finite-area scheme is presently used to difference the two-dimensional unsteady Euler equations and yield, in local subregions near oscillating turbomachine blades, moving grids possessing equal-difference distribution. This method is noted to not only facilitate the grids' fitting of the cascades, but to economize on computation time as well. The calculation results obtained are found to agree with oscillating cascade measurements, and show that the interaction between inlet perturbation and oscillating cascade in the condition with averaged pressure gradient can qualitatively modify the aerodynamic damping of the cascade system. O.C.

**A90-11793#**

### **UNSTEADY AERODYNAMIC CHARACTERISTICS OF OSCILLATING CASCADE WITH TIP CLEARANCE**

TOSHINORI WATANABE (Tokyo Noko University, Koganei, Japan) and SHOJIRO KAJI (Tokyo, University, Japan) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 405-435. refs

The present experimental and theoretical study of the aerodynamics of oscillating linear cascades with tip clearances has proceeded by obtaining chordwise and spanwise blade direction pressure measurements as tip clearances were varied from 0.056 to 2.8 percent of blade-span. Tip clearance is experimentally found to strongly influence the distribution of unsteady aerodynamic forces along the blade span; under steady aerodynamic loading, however, tip-clearance influence is suppressed. The bladetip vortex increases the absolute value of the steady aerodynamic force in the tip region. Vortex lattice method-based calculations have yielded the unsteady aerodynamic forces acting on oscillating blades with tip clearances. O.C.

### **A90-11806\*# California State Univ., Long Beach. PROGRESS TOWARDS THE DEVELOPMENT OF AN INVISCID-VISCOUS INTERACTION METHOD FOR UNSTEADY FLOWS IN TURBOMACHINERY CASCADES**

T. CEBECI (California State University, Long Beach), M. F. PLATZER, N. G. TENG, A. KRAINER (U.S. Naval Postgraduate School, Monterey, CA), and R. J. SIMONEAU (NASA, Lewis Research Center, Cleveland, OH) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of

Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 721-753. refs

The velocity and heat transfer characteristics of blade passage flows subject to onset velocities that vary in space and time are calculated by means of a general method involving the solution of inviscid and boundary-layer equations coupled with the Hilbert integral. The performance of this boundary layer method for flows with prescribed pressure distribution is evaluated in terms of two model problems that give attention to the stagnation region. One model corresponds to an oscillating airfoil with moving stagnation point; the other is a simulation of a blade which is subject to a uniform onset velocity. O.C.

**A90-11807#**

### **COMPUTATION OF UNSTEADY COMPRESSIBLE TURBULENT BOUNDARY LAYERS IN CASCADE FLOW WITH CONTROLLED INLET PERTURBATION**

LI HE and SHENG ZHOU (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 755-767. refs

A numerical solver has been developed for the flow field of unsteady compressible turbulent boundary layers, in the interest of a method for the active suppression of flow separation on blades by means of controlled inlet perturbations. The momentum and energy equations are solved in two different ways, and an actual unsteady boundary layer is calculated. It is found that, in the conditions of cascade flow with inlet unsteady total pressure perturbation for which three different turbulent boundary layers are presently calculated, the average vorticity in the boundary layer is transferred to the wall under an inverse pressure gradient. O.C.

**A90-11808#**

### **SELF-EXCITED OSCILLATION OF SHOCK WAVES ON AN AIRFOIL IN TWO-DIMENSIONAL TRANSONIC CHANNEL FLOW**

K. YAMAMOTO and Y. TANIDA (Tokyo, University, Japan) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 769-783. refs

A self-excited oscillation of the shock waves in the transonic flow around a simplified cascade model was investigated by measuring the unsteady static pressure field and the boundary layer thickness. The results ensemble-averaged over one cycle of oscillation clearly show the relation between the shock wave motion, the instantaneous pressure field and the separated boundary-layer behavior. The fluctuation of the boundary layer separated at the shock foot produces the large pressure disturbance downstream of the shock wave, which propagates to cause the variation of the shock wave location and strength. The shock waves then oscillate in anti-phase manner on each side of the airfoil. As a result, the self-excited oscillation is continued. Author

**A90-11849#**

### **NUMERICAL SIMULATION OF REVERSED FLOW OVER A SUPERSONIC DELTA WING AT HIGH ANGLE OF ATTACK**

W. PHILLIP WEBSTER and JOSEPH S. SHANG (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, Fluid Dynamics, Plasma Dynamics, and Lasers Conference, 20th, Buffalo, NY, June 12-14, 1989. 10 p. refs (AIAA PAPER 89-1802)

Steady flow fields describing the supersonic flow over a 75 deg sweep delta wing at four angles of attack (10, 20, 30 and 35 deg) are calculated. Time integration is used to solve the unsteady three-dimensional compressible laminar thin-layer Navier-Stokes equations. Comparison between the present solution and previous

calculations and experimental data at the lower angles of attack indicate that the essential structure has been captured. At 30 and 35 deg angles of attack, large regions of reversed flow were observed near the trailing edge. The reversed flow extends upward from the surface and is contained in the secondary vortex.

Author

**A90-11873#**

**FINITE ELEMENT METHOD FOR UNSTEADY THREE-DIMENSIONAL SUBSONIC FLOWS THROUGH A CASCADE OSCILLATING WITH STEADY LOADING**

NOBUHIKO YAMASAKI, MASANOBU NAMBA (Kyushu University, Fukuoka, Japan), and KUO-CHENG YANG Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 32, Aug. 1989, p. 51-66. refs

The paper presents a finite element method formulation to calculate unsteady aerodynamic force for three-dimensional oscillating cascades in subsonic flows. Three-dimensional small unsteady perturbations superimposed on a spanwise uniform steady flow are treated. Numerical calculations have been conducted to investigate the three-dimensional effects upon unsteady aerodynamic force for various combinations of the interblade phase angle, mean angle of attack, camber, thickness, aspect ratio and vibration mode.

Author

**A90-12023**

**COLLOCATION METHODS AND LIFTING-SURFACES**

J.-L. GUERMOND (Bassin d'Essais des Carenes, Paris, France) European Journal of Mechanics, B/Fluids (ISSN 0997-7546), vol. 8, no. 4, 1989, p. 283-305. refs

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A mathematical formulation is presented to treat the tip and the leading-edge singularities along with the Cauchy type singularities occurring in the calculation of the velocity induced on a linearized lifting-surface. Several discretization schemes are reviewed together with their respective error bounds. The force calculation problem is addressed and a numerical scheme is proposed to calculate separately the pressure induced forces and the leading-edge suction.

Author

**A90-12218#**

**MEASUREMENTS OF PRESSURE FLUCTUATIONS IN THE INTERACTION REGIONS OF SHOCK WAVES AND TURBULENT BOUNDARY LAYERS INDUCED BY BLUNT FIN**

SHIGERU ASO, ANZHONG TAN, SEISHI KURANAGA, and MASANORI HAYASHI Kyushu University, Technology Reports (ISSN 0023-2718), vol. 62, March 1989, p. 149-155. In Japanese, with abstract in English. refs

The wall pressure fluctuations are measured in the interaction regions of shock waves and turbulent boundary layers induced by blunt fins with hemicylindrical leading edges. Two kinds of fins with leading-edge diameters of 6 mm and 10 mm are used to examine the influence of leading-edge diameter on the flow-field properties. Experiments are performed at a Mach number of 4, Reynolds number of  $1.27 \times 10$  to the 7th, and under the wall temperature condition  $T_w/T_0$  of 0.68. The wall pressure fluctuations get strong at the primary separation lines, the secondary separation lines and the primary reattachment lines. The results show that the boundary layer separation and reattachment have close relations to the unsteady properties of the flow field. From the comparison of the results of the two different fins, it seems that the scale of the unsteady properties of the flow field is mainly dominated by the leading edge diameters.

Author

**A90-12219#**

**NUMERICAL CALCULATION OF UNSTEADY AERODYNAMIC FORCES FOR THREE-DIMENSIONAL SUBSONIC OSCILLATING CASCADES BY A FINITE ELEMENT METHOD**

NOBUHIKO YAMASAKI, MASANOBU NAMBA (Kyushu University, Fukuoka, Japan), and KUO-CHENG YANG Kyushu University, Faculty of Engineering, Memoirs (ISSN 0023-6160), vol. 49, March 1989, p. 1-15. refs

This paper presents a finite element method formulation to

calculate unsteady aerodynamic force for three-dimensional oscillating cascades in subsonic flows. Three-dimensional small unsteady perturbations superimposed on a spanwise uniform steady flow are treated. Numerical calculations have been conducted to investigate the three-dimensional effects upon unsteady aerodynamic force for various combinations of the reduced frequency, interblade phase angle, mean angle of attack, camber, thickness, aspect ratio and vibration mode.

Author

**A90-12220#**

**AERODYNAMIC HEATING IN THE INTERACTION REGIONS OF SHOCK WAVES AND TURBULENT BOUNDARY LAYERS INDUCED BY SHARP FINS**

SHIGERU ASO (Kyushu University, Fukuoka, Japan), MASANORI HAYASHI (Nishi-nihon Institute of Technology, Fukuoka, Japan), and ANZHONG TAN Kyushu University, Faculty of Engineering, Memoirs (ISSN 0023-6160), vol. 49, March 1989, p. 69-80. refs

A study on aerodynamic heating in the interaction regions of shock waves and turbulent boundary layers induced by sharp fins is performed under the conditions of Mach number 4, total pressure 1.2 MPa, the ratio of wall temperature to total temperature 0.63-0.66, and Reynolds number  $1.2 \times 10$  to the 7th. Attack angles of fins are selected as 4, 10, and 16 degrees, to investigate the cases of incipient, primary, and secondary separation of the boundary layers. For the measurements of heat transfer rates, a new type of multilayered thin-film heat-transfer gauge was developed. The results show that the distributions of surface pressure and heat transfer change drastically as the attack angles of fins are increased. In separated cases the peak heatings occur along the primary reattachment lines.

Author

**A90-12229#**

**AN APPLICATION OF THE SURFACE-SINGULARITY METHOD TO WING-BODY-TAIL CONFIGURATIONS**

JANG-SOO CHOI, YOSHIYUKI SUGIYAMA (Nagoya University, Japan), and KEUN-SHIK CHANG (Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea) Nagoya University, Faculty of Engineering, Memoirs (ISSN 0027-7657), vol. 40, no. 2, 1988, p. 337-350.

A computer code based on the 1st order panel method is presented for solving inviscid incompressible flow fields about 3-D airplane-like bodies. A sample problem chosen for a test is solved and a comparison with other computational results shows good agreement. To increase the accuracy of the method, especially for a thin wing, the number of doublet panels on the camber surface of a wing is multiplied in the chordwise direction by a factor, which enhances the accuracy to some extent.

Author

**A90-12238#**

**NUMERICAL CALCULATION OF UNSTEADY AERODYNAMIC FORCES FOR TWO-DIMENSIONAL SUPERSONIC OSCILLATING CASCADES BY FINITE ELEMENT METHOD**

KUO-CHENG YANG and MASANOBU NAMBA Kyushu University, Technology Reports (ISSN 0023-2718), vol. 62, June 1989, p. 239-246. In Japanese, with abstract in English. refs

Calculation by a finite element method has been conducted to study unsteady aerodynamic forces for two-dimensional oscillating cascades in supersonic flows. In the case of lightly loaded cascades, unsteady aerodynamic forces are dominated by the effect of displacement of an oblique shock reflection point, destabilizing a translational blade motion at some interblade phase angles. In the case of moderately or highly loaded cascades with a normal shock in the blade passage also the unsteady pressure is locally high near the shock position, but the translational blade motion is generally stabilized.

Author

**A90-12267**

**IRREGULAR INTERACTION OF A STRONG SHOCK WAVE WITH A THIN PROFILE [NEREGULIARNOE VZAIMODEISTVIE SIL'NOI UDARNOI VOLNY S TONKIM PROFILEM]**

V. I. BOGATKO and G. A. KOLTON Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiia (ISSN 0024-0850),

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July 1989, p. 45-49. In Russian. refs  
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The problem of the irregular reflection of a strong shock wave from a curved wall is analyzed assuming small values of the relative profile thickness and density ratio at the front of the incident shock wave. The problem is reduced to a system of integrodifferential equations, for determining the diffracted shock wave front, and quadratures. In the self-similar case of the reflection of a strong shock wave from a wedge, the problem is reduced to that of integrating an ordinary differential equation to determine the Mach wave front. V.L.

**A90-12268**

**ASYMPTOTIC CALCULATION OF FLOW PARAMETERS IN THE PROBLEM OF HYPERSONIC FLOW PAST BLUNT AXISYMMETRIC BODIES [ASIMPTOTICHESKII RASCHET PARAMETROV POTOKA V ZADACHE GIPERZVUKOVOGO OBTEKANIIA ZATUPLennykh OSESIMMETRICHNYKH TEL]**

S. A. IVANOV, I. V. MAKIN, and V. N. ENGEL'GART Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiia (ISSN 0024-0850), July 1989, p. 53-57. In Russian. refs  
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The two-dimensional stationary problem of flow of an ideal gas past smooth blunt bodies is analyzed for the case where the effective adiabatic exponent is close to one and the Mach number approaches infinity. The solution is constructed in two-parameter asymptotic form to a second approximation. A comparison with the available results indicates that the asymptotic formulas are valid over a wide range of adiabatic exponents and free-stream Mach numbers. V.L.

**A90-12279**

**PRESSURE PULSATION IN A CAVITY IN THE PATH OF SUBSONIC AND SUPERSONIC GAS FLOW [PUL'SATSII DAVLENIIA V VYEMKE, OBTEKAEMOI DOZVUKOVYM ILI SVERKHZVUKOVYM POTOKOM GAZA]**

A. N. ANTONOV and K. N. FILIPPOV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), July-Aug. 1989, p. 84-89. In Russian. refs  
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Pressure pulsations generated in the case of subsonic and supersonic flow past an open cavity were investigated experimentally. The pressure pulsation spectrum includes continuous and discrete components. The effect of flow parameters on the levels of the continuous and discrete components of pressure pulsations in the cavity is determined. V.L.

**A90-12281**

**LEE-SIDE HEATING OF A DELTA WING IN SUPERSONIC FLOW [O NAGREVANII PODVETRENNOI STORONY TREUGOL'NOGO KRYLA PRI SVERKHZVUKOVOM OBTEKANII]**

V. N. BRAZHKO, N. A. KOVALEVA, L. A. KRYLOVA, and G. I. MAIKAPAR PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), July-Aug. 1989, p. 106-112. In Russian. refs  
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Results of several earlier studies of the flow structure and heat transfer on the upper surface of a delta wing are briefly reviewed. Results of an experimental investigation of the lee-side heating of a delta wing in supersonic flow ( $M = 3, 4$ , and  $5$ ) are then reported. In particular, attention is given to criteria for the existence of specific types of separated flow, effect of flow scheme on heat transfer, and effect of Mach and Reynolds numbers and wing surface configurations on the lee-side aerodynamic heating of the wing. V.L.

**A90-12282**

**AN EXPERIMENTAL STUDY OF FLUCTUATIONS IN THE FRONT SEPARATION ZONE AT SUPERSONIC FLOW VELOCITIES [EKSPERIMENTAL'NOE ISSLEDOVANIE PUL'SATSII V PEREDNEI OTRYVNOI ZONE PRI SVERKHZVUKOVOI SKOROSTI POTOKA]**

V. I. ZAPRIAGAEV and S. G. MIRONOV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), July-Aug. 1989, p. 116-124. In Russian. refs  
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Experimental data are presented on pressure fluctuations and discrete tone frequencies for a model with variable geometry of the front separation zone. The results of a combined analysis of the motion of shock waves ahead of a spike-tipped cylinder and pressure fluctuations at the cylinder end are presented, and the mechanism of the fluctuations is discussed. A criterion is obtained for the relative mass transfer in the case of fluctuations in the separation region. V.L.

**A90-12284**

**HYPERSONIC FLOW PAST BLUNT EDGES AT LOW REYNOLDS NUMBERS [GIPERZVUKOVOE OBTEKANIE ZATUPLennykh KROMOK PRI MALYKH CHISLAKH REINOL'DSA]**

A. V. BOTIN, V. N. GUSEV, and V. P. PROVOTOROV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), July-Aug. 1989, p. 161-168. In Russian. refs  
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Flow past the blunt edges and nose sections of a hypersonic flight vehicle is analyzed for small Reynolds numbers in the context of the theory of a thin viscous shock layer. Calculations are carried by the finite-difference method for flows of axial and plane symmetries over a wide range of similarity parameters. The use of cooling gas injection for reducing heat flows to the body is discussed. The results obtained are found to be in good agreement with experimental data. V.L.

**A90-12510#**

**NUMERICAL SIMULATION OF TURBOMACHINERY FLOWS WITH A SIMPLE MODEL OF VISCOUS EFFECTS - COMPARISON WITH EXPERIMENTAL DATA**

G. MEAUZE, J. PAULON (ONERA, Chatillon-sous-Bagneux, France), and D. DEHONDT (Turbomeca, Bizanos, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 100-108. refs  
(ONERA, TP NO. 1989-122) Copyright

A simple model of viscous effects, which retains the simplicity of the Euler equations, is defined. Loss schematization is described with consideration given to viscous effect simulation, peripheral gap effects simulation, and characterization of the unsteady flow downstream of the rotor. Examples are presented of a calculated meridional angle downstream of a BARON rotor. K.K.

**A90-12512#**

**EVALUATION OF TWO NUMERICAL TECHNIQUES FOR THE PREDICTION OF FLOW AROUND BLADES**

P. TAMAMIDIS, P. PRINOS, and A. GOULAS (Salonika, University, Greece) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 119-124. refs  
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Two techniques used to predict the flow around an airfoil cascade are described. The first method is based on a stream function formulation for the inviscid flow and an integral boundary layer method for the viscous and turbulent effects. The second technique is a primitive variable pressure correction technique in which a nonorthogonal nonstaggered grid arrangement was implemented. For the first method, the absence of a wake model and the satisfaction of the Kutta condition caused separation near the trailing edge even at zero incidence. K.K.

**A90-12517#**

**STUDIES ON THE INFLUENCE OF MACH NUMBER ON PROFILE LOSSES OF A REACTION TURBINE CASCADE**

N. VENKATRAYULU, A. DASGUPTA, and K. M. SRIVASTAVA (Indian Institute of Technology, Madras, India) IN: International

Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 173-181. refs  
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Detailed aerodynamic investigations were carried out on a typical 50 percent reaction blade profile to evaluate and generate the performance data and to identify the Mach number range above which the blade profile may not be suitable for operation due to high-profile losses. The work was designed to develop a small high-speed cascade tunnel and to carry out experimental investigations on the reaction turbine blade profile for the exit flow surveys and the blade surface static pressure distribution for various inlet flow angles and exit Mach numbers. The dependence of the cascade loss on Mach number and Reynolds number was evaluated from experimental data. K.K.

#### A90-12518#

##### **SHOCK CAPTURING AND LOSS PREDICTION FOR TRANSONIC TURBINE BLADES USING A PRESSURE CORRECTION METHOD**

JOHN MOORE and JOAN G. MOORE (Virginia Polytechnic Institute and State University, Blacksburg) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 182-188. Research supported by Rolls-Royce, PLC. refs  
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The extensions necessary to allow a pressure correction method to handle supersonic flow with shock-capturing are presented. These developments parallel the extensions used in explicit time marching methods to calculate subsonic flow. A stability analysis is used to develop a pressure interpolation equation which allows shocks to be captured over a few grid steps. The new pressure correction method is demonstrated with calculations of shock boundary layer interaction and flow separation in a transonic diffuser and trailing edge shocks in a transonic turbine blade row. Author

#### A90-12519#

##### **INFLUENCE OF BLADE LEANING ON THE FLOW FIELD BEHIND TURBINE RECTANGULAR CASCADES WITH DIFFERENT INCIDENCES AND ASPECT RATIOS**

ZHONGQI WANG, WANJIN HAN, DAYING CAI, and WENYUAN XU (Harbin Institute of Technology, People's Republic of China) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 189-196. refs  
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The flow field behind turbine rectangular static cascades with different incidences and aspect ratios was measured in a low-speed plane cascade tunnel. Particular attention is given to the effect of blade deflection on the aerodynamic behaviors of flow fields behind the cascades. It is found that, in the case of different incidences and aspect ratios, the use of deflected blades can improve the aerodynamic properties on the acute-angle side of the rectangular cascades. K.K.

#### A90-12520#

##### **AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF INCIDENCE ON THE TWO-DIMENSIONAL PERFORMANCE OF AN AXIAL TURBINE CASCADE**

S. M. GOOBIE, S. A. SJOLANDER (Carleton University, Ottawa, Canada), and S. H. MOUSTAPHA (Pratt and Whitney Canada, Montreal; Carleton University, Ottawa, Canada) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 197-204. Research supported by NSERC and Pratt and Whitney Canada. refs  
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There is a great need for additional data on the off-design performance of turbines, particularly for airfoils of recent design.

The present work provides data on the measured two-dimensional performance of a linear turbine cascade with a turning angle of 87 degrees which was tested at -15, 0 and +15 degrees of incidence. Results are presented for the blade surface pressures, total pressure losses and exit flow angle deviations. The measured losses compared very well with those predicted by a recently developed correlation. Data are also presented on the effect of Reynolds number and the downstream traverse location on the measured midspan losses. Author

#### A90-12521#

##### **FLOW IN COMPRESSOR INTERSTAGE DUCTS**

H. A. ABDALLA and S. SOUNDTRANAYAGAM (Indian Institute of Science, Bangalore, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 207-215. Research supported by the Aeronautical Development Agency and Aeronautical Research and Development Board. refs  
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Detailed measurements have been made in a compressor interstage duct with special emphasis on the development of the boundary layers and the distribution of the fluid stresses. An inviscid finite volume time marching computational program iteratively coupled with an integral boundary layer calculation scheme has been used to predict the flow in the duct. The program has also been used to calculate the flow in interstage ducts with bypass. The boundary layer blockage and loss in total pressure are particularly well predicted. Author

#### A90-12524#

##### **A STUDY OF FLOW STRUCTURE IN A CONTRA-ROTATING AXIAL COMPRESSOR STAGE**

P. B. SHARMA and D. S. PUNDIR (Indian Institute of Technology, New Delhi, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 237-244. Research supported by the Aeronautical Research and Development Board. refs  
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An experimental investigation into performance improvements in an axial compressor stage using a pair of contra-rotating rotors is presented. Flow structure up and downstream of rotors is examined to illustrate aerodynamic performance changes due to change in speed ratio and axial gap between the rotors. The existence of an upstream gauze is shown to effect the stalling behavior of the stage. Author

#### A90-12525#

##### **THE INTERACTION BETWEEN TIP CLEARANCE FLOW AND THE PASSAGE FLOWFIELD IN AN AXIAL COMPRESSOR CASCADE**

J. A. STORER (Cambridge University, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 245-253. Research supported by Rolls-Royce, PLC. refs  
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Some aspects of the flow interaction that takes place between tip leakage flow and the rest of the flowfield are studied. Particular attention is given to the mechanism of total pressure loss reduction. In the cascade with zero tip clearance, a separation was observed on the suction surface of the blade near the corner with the endwall. This was responsible for a significant loss of total pressure measured downstream of the cascade. K.K.

#### A90-12526#

##### **AN INVESTIGATION OF ARTIFICIAL COMPRESSOR SURGE**

GUO CAI TANG and HUI MING ZHANG (Nanjing Aeronautical Institute, People's Republic of China) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of

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Aeronautics and Astronautics, 1989, p. 254-261. refs  
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It is shown that artificial surge may be created by external perturbation to a compression system. Cases in which the nonlinear dynamic fluid model can successfully predict artificial surge are pointed out. It is suggested that artificial surge may be useful for investigating unsteady flow phenomena in turbomachinery. K.K.

**A90-12527#**

### **UNSTEADY LOSS IN A LOW SPEED AXIAL FLOW COMPRESSOR DURING ROTATING STALL**

F. A. E. BREUGELMANS (Institut von Karman de Dynamique des Fluides, Rhode-Saint-Genese, Belgium), L. HUANG, L. LAROSILIERE, and P. ANDREW IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 262-270. refs  
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The investigation of the instantaneous loss-incidence angle relation of an axial compressor blade section is performed. Fast response instrumentation, mounted on the rotor, is used for triggering and data acquisition of relative total pressure traces at 16 tangential positions distributed over one pitch. The application of FFT and phase averaging techniques provides the averaged time resolved pressure evolution during one rotating stall event. The synchronization of the relative flow angle and pressure traces permits the construction of the blade-to-blade total pressure profile at every instant of the cell occurrence. The instantaneous loss-inlet angle characteristic is derived and an error band defined. The unsteady behavior of the compressor blade is demonstrated.

Author

**A90-12549#**

### **NAVIER-STOKES METHODS APPLIED TO TURBOMACHINERY BLADE DESIGN**

P. STOW (Rolls-Royce, PLC, Derby, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 473-484. refs  
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The Navier-Stokes methods are applied to the design of turbomachinery blades, within the framework of a blade-design system based on the Wu theory (1952), using quasi-three-dimensional through-flow and blade-to-blade program. Basic capabilities of this system are demonstrated together with limitations of the boundary layer approach and the need for the Reynolds averaged Navier-Stokes methods in removing these limitations. Results from both the time-marching and pressure-correction methods being presently developed for compressors and turbines are presented. I.S.

**A90-12551#**

### **THE DEVELOPMENT OF AN EXACT CONSERVATIVE SCHEME ASSOCIATED WITH THE SUPERSONIC TRAILING EDGE SEPARATION MODELLING FOR THE COMPUTATION OF THE TRANSONIC 2D CASCADE**

T. S. LUU and Q. LAN (CNRS, Laboratoire d'Informatique pour la Mecanique et les Sciences de l'Ingenieur, Orsay, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 490-496. refs  
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An exact conservative scheme using the concept of the flow structure modification through the sub to supersonic region is presented. It is no longer necessary to introduce the density biasing to stabilize the solution, as in most computational transonic schemes. The full potential equation is solved in conservative form by an implicit method based on a local flux linearization. This scheme is associated with an adequate supersonic trailing edge separation modeling for the computation of the transonic two-dimensional cascades. Results corresponding to the transonic

flow through a turbine cascade for various back pressure setting in the choked ranges with supersonic outlet are presented.

Author

**A90-12553#**

### **BOUNDARY LAYER GROWTH ON LOW ASPECT RATIO COMPRESSOR BLADES**

G. ABDUL QUADIR and S. SOUNDARANAYAGAM (Indian Institute of Science, Bangalore, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 509-517. refs  
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Lateral convergence of the streamlines and blockage strongly affect the boundary layer growth on compressor blades. Wind tunnel measurements in a cascade of compressor blades of unit aspect ratio show a faster growth of boundary layers and delay in transition compared to two-dimensional flows. The boundary layers also remain attached and unseparated at very high values of the shape factor. The increased rate of growth of the momentum thickness of the boundary layer can be predicted if convergence effects are introduced, but it needs values of local convergence to be assumed much higher than that measured overall. Author

**A90-12554#**

### **A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE REYNOLDS AND APPARENT STRESSES IN AXIAL COMPRESSORS**

O. C. JADAYEL (Birmingham, University, England) and J. W. RAILLY IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 518-528. Research supported by the Hariri Foundation. refs  
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The three-dimensional flow field which exists downstream of an axial compressor rotor was measured using hot-wire anemometers. Successive sampling of instantaneous signals obtained from a three-wire probe at phase-locked positions relative to the rotor permitted the blade-to-blade mean flow and turbulence properties to be calculated. The apparent stress tensor which acts only on the absolute mean flow was of particular interest and was deduced from local time-mean and pitch-wise mean velocity components. The experimental results reveal high turbulence levels in the hub, tip, and wake regions, suggesting that turbulent mixing is the main mechanism by which momentum transport and energy dissipation take place. A theoretical S2-type calculation which models the turbulent effects in the compressor on the basis of a macroscopic eddy viscosity is presented and is used to determine the irreversibilities brought about by the mixing process. Author

### **A90-12555\*# PENNSYLVANIA STATE UNIV., UNIVERSITY PARK. COMPUTATION OF THREE DIMENSIONAL TURBULENT BOUNDARY LAYERS IN INTERNAL FLOWS, INCLUDING TURBOMACHINERY ROTOR BLADES**

J. ZHANG and B. LAKSHMINARAYANA (Pennsylvania State University, University Park) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 529-538. refs  
(Contract NSG-3266; NSF INT-87-02083)  
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A method is developed for predicting three-dimensional turbulent boundary layers occurring in internal flows, including rotor blades of turbomachinery. These boundary layers are complex, turbulent, and are subject to Coriolis and centrifugal forces. The algebraic Reynolds stress model (ARSM) developed in this paper satisfies the realizability conditions exactly and captures the changes in turbulent structure arising from curvature and rotation. The prediction of pressure driven secondary flow agrees well with the data and all the three turbulent models (k-e, algebraic eddy viscosity, and ARSM) show the same level of agreement. The prediction of boundary layer on rotor blades shows much better



agreement with the ARSM. It is essential to employ the higher order models to capture the effects of rotation and curvature and three-dimensional boundary layers in turbomachinery. Author

#### A90-12557#

##### **TURBOMACHINERY TIP GAP AERODYNAMICS - A REVIEW**

R. E. PEACOCK (Pisa, Universita, Italy) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 549-559. Research supported by the U.S. Navy. refs  
Copyright

An uncoordinated history of experiment with cascades, compressors, pumps and turbines has yielded data on leakage flows in tip regions of axial flow turbomachines. This review is an attempt to collate and relate this information. Performance suffers as the tip clearance grows, both in compressors and turbines and the level of agreement found is noteworthy. The concept of an optimum tip gap is questioned, particularly in view of engineering considerations for normal installations. The inter-activity between the tip gap and rotating stall is highlighted. Suggestions made for research potentially useful to the designer and operator of turbomachinery, include further examination of tip treatment and stall limiting effects. Author

#### A90-12576#

##### **AXISYMMETRIC AFTERBODY FLOW SEPARATION AT TRANSONIC SPEEDS IN PRESENCE OF JET EXHAUST**

N. B. MATHUR and K. S. YAJNIK (National Aeronautical Laboratory, Bangalore, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 731-737. refs  
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The separated transonic-interaction characteristics of an axisymmetric boat-tailed afterbody configuration were investigated using a model consisting of an equivalent body of revolution of a representative combat aircraft configuration and a 0.3 trisonic wind tunnel. Experiments were carried out in the free stream Mach number range of 0.98 to 1.21 at constant free stream Reynolds number of  $35 \times 10$  to the 6th/m, keeping the model at 0-deg incidence. Results show that an increase of free stream Mach number in the transonic range caused the separated flow region to move downstream toward the boat-tail end, while an increase in jet pressure ratio caused the upstream movement of the separated flow locations over the boat-tail. I.S.

#### A90-12582#

##### **VSTOL POWER PLANT CONTROL LESSONS FROM HARRIER EXPERIENCE**

A. J. NORTHOTT (Rolls-Royce, PLC, Bristol, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 782-789. Research supported by the Ministry of Defence Procurement Executive.  
Copyright

The Pegasus engine in the Harrier has provided Rolls-Royce with unrivalled experience in fixed wing VSTOL aircraft propulsion. From the control system point of view, the Pegasus is especially interesting because the well-developed hydromechanical fuel control has been superseded by a digital electronic control system (DECS). This paper outlines some of the lessons learned from this experience on the control of VSTOL power plants. The use of this experience for future STOL and VSTOL concepts is explored. Author

#### A90-12586#

##### **TANGENTIAL MASS ADDITION FOR THE CONTROL OF SHOCK WAVE/BOUNDARY LAYER INTERACTIONS IN SCRAMJET INLETS**

M. E. WHITE, R. E. LEE, M. W. THOMPSON, A. CARPENTER (Johns Hopkins University, Laurel, MD), and W. J. YANTA (U.S.

Navy, Naval Surface Warfare Center, White Oak, MD) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 815-823. Research sponsored by USAF and U.S. Navy. refs  
Copyright

A series of tests are performed to investigate and characterize shock wave/boundary layer interactions typical of hypersonic inlets and to develop methods of controlling, through the use of tangential mass injection, regions of shock-induced separation. The major objectives are accomplished in a multiphase experimental test program with complementary application of computational techniques. Presented herein are results from an entry into NSWC/WO Tunnel 2 during the proof-of-concept phase of testing. The feasibility of using Mach 3 tangential air injection to eliminate separation associated with the cowl-shock/innerbody boundary layer interaction in a scramjet inlet model has been demonstrated. Also, the results of a Navier-Stokes computational flowfield solution applied to the tested inlet are presented. Author

#### A90-12587#

##### **NUMERICAL SIMULATION OF THREE-DIMENSIONAL HYPersonic INLET FLOWFIELDS**

T. P. GIELDA and R. K. AGARWAL (McDonnell Douglas Corp., Saint Louis, MO) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 824-833. refs  
Copyright

A three-dimensional finite-volume/finite-rate parabolized Navier-Stokes code (MDC-FPNS3D) was modified to compute hypersonic inlet flowfields. Code calibration studies were performed to determine optimum computational grid requirements. Grid density effects were quantified through comparisons of computed solutions with experimental data. In addition, grid density effects on global parameters such as computed mass flow and computed kinetic energy efficiency were determined. Author

#### A90-12590#

##### **NUMERICAL ANALYSIS OF ROTATING STALL BY A VORTEX MODEL**

TOSHIO NISHIZAWA and HIROYUKI TAKATA (Tokyo, University, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 854-863. refs  
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Flow behavior of rotating stall in a linear cascade of NACA 65(CA30)10 blades with solidity of 1.0 and stagger angle of 30 degrees is studied numerically. The numerical method which was developed for two-dimensional incompressible separated flows of high Reynolds number around an isolated blade has been extended and used for cascades of blades. Flow behavior and timewise variation of mass flow through each blade passage clearly show the propagative features of rotating stall for a wide range of inlet flow angles. The phenomenon of stall vortex shedding, which is similar as occurred around isolated blades, is observed to occur in the stall cells. The physical characteristics of rotating stall seem to be well understood in terms of the features of these vortices. The total pressure loss performance of the cascade is examined for both stalled and unstalled flow regimes. The static pressure and the velocity distributions ahead of the cascade are compared with the features of the actuator disk analyses. Author

#### A90-12592#

##### **EXPERIMENTAL INVESTIGATION OF THE TRANSONIC CENTRIFUGAL COMPRESSOR INDUCER STRAIGHT CASCADES**

K. CELIKOVSKY (Vyzkumny a Zkusebni Letecky Ustav, Prague, Czechoslovakia) and P. SAFARIK (Ceskoslovenska Akademie Ved, Ustav Termomechaniky, Prague, Czechoslovakia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept.

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3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 873-880. refs  
Copyright

The paper discusses the results of straight cascade measurements in supersonic wind tunnel, modeling the operation of the centrifugal compressor transonic inducer tip sections. The influence of splitter position both on the velocity distribution along the airfoils chords and suction side flow separation is specified. Wind tunnel simulation of the impeller geometrical constraints for the inducer section by means of airfoils straight plate endings is presented. Author

**A90-12595#**

### **AN EXPERIMENTAL INVESTIGATION OF NON-STEADY FLOW IN VANELESS DIFFUSERS**

MOHAMMAD I. ANJUM and CHARLES A. GARRIS (George Washington University, Washington, DC) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 895-904. refs  
Copyright

An experimental program has been conducted to ascertain the characteristics of the nonsteady flow in the vaneless exit flow diffuser of a centrifugal compressor. Attention is given to the total pressure loss and the static pressure rise of the flow at various locations in the vaneless diffusers, with rotors of two and four nozzles as well as both backward and forward nozzle discharge angles. A comparison of the results obtained with existing vaneless diffuser theories indicates that vaneless diffusers are inefficient in the collection and diffusion of nonsteady flows; efficiency improves with decreasing nonsteadiness. O.C.

**A90-12596#**

### **RADIAL SWIRL FLOWS BETWEEN PARALLEL DISKS AT CRITICAL FLOW RATE**

T. NAGASHIMA (Tokyo, University, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 905-913. refs  
Copyright

The phenomenon of flow instability, as in the rotating stall that occurs as flow rate is reduced below a critical value, is experimentally investigated in vaneless diffusers of the type used in centrifugal pumps and compressors. The mean flow angle plotted as a curve of flow angle vs flow rate yields a critical condition for the occurrence of rotating stall in the range of 74-78 deg to the radial direction, at the diffuser inlet ratio. Upon reduction of the flow rate, a locally reversed flow region was noted to be already present before the flow angle exceeded the critical value at one of the side walls near the inlet region. O.C.

**A90-12597#**

### **A SECONDARY FLOW CALCULATION METHOD FOR ONE STAGE CENTRIFUGAL COMPRESSOR**

D. DOUVIKAS, J. KALDELLIS, and K. D. PAPAILIOU (Athens, National Technical University, Greece) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 914-927. refs  
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The present secondary flow calculation method for a one-stage centrifugal compressor employs the meridional vorticity transport equation in conjunction with the Navier-Stokes equations. While the method is integral in the meridional direction, it is differential in the peripheral direction. Emphasis is placed on the use of a coherent two-zone model as well as an approximate model of the interaction between viscous shear layers and the external flow; both meridional and peripheral blockage are taken into account. Care is taken to distinguish between unbounded (external), semibounded (annular), and fully bounded (banded) stages of centrifugal compression. O.C.

**A90-12598#**

### **UNSTEADY FLOW IN CENTRIFUGAL COMPRESSORS DUE TO DOWNSTREAM CIRCUMFERENTIAL DISTORTIONS**

M. T. SIDERIS and R. A. VAN DEN BRAEMBUSSCHE (Institut von Karman de Dynamique des Fluides, Rhode-Saint-Genese, Belgium) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 928-936. refs  
Copyright

A numerical model has been used to systematically investigate the response of a centrifugal compressor impeller to downstream circumferential static pressure distortions. Different reduced frequencies are simulated in order to evaluate the variations of impeller response as a function of distortion frequency, as well as to define resonance conditions. Attention is given to the influence of the various frequencies contained in a sawtooth-waveform distortion on impeller flow unsteadiness. Calculated circumferential variations of velocity and flow angle are compared with experimental measurements. O.C.

**A90-12614#**

### **PROPELLER WAKES AND THEIR INTERACTION WITH WINGS**

R. T. JOHNSTON, D. WITKOWSKI, and J. P. SULLIVAN (Purdue University, West Lafayette, IN) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1070-1077. refs  
Copyright

Studies to present on the propeller wake structure, and the subsequent interaction with a wing has revealed some interesting details. Laser velocimeter measurements in the flowfield of an isolated propeller have yielded the wake topography. Steady state force measurements on a propeller/wing tractor configuration reveal a thrust enhancement or conversely a wing drag reduction. Flow visualization of the propeller tip vortex as it passes the wing discloses information about the unsteady nature of the propeller wake/wing interaction. Author

**A90-12621#**

### **COMPUTATION OF TRANSONIC TURBINE CASCADE FLOW USING NAVIER-STOKES EQUATIONS**

H. ZIMMERMANN and D. SCHWAMBORN (DLR, Goettingen, Federal Republic of Germany) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1145-1152. refs  
Copyright

An explicit Runge-Kutta integration technique for the compressible time-dependent Navier-Stokes equations is applied to predict the flow through a linear turbine cascade operating in the transonic flow regime. The finite volume approach uses a block structure to increase the flexibility of the code. The computational results are compared to experimental data. The influence of possible three-dimensional effects in the experiments is investigated by three-dimensional computations taking the sidewalls into account. Results are shown for the MTU-T5.1 profile at isentropic outflow Mach numbers of 0.7, 0.9, and 1.1. Author

**A90-12622#**

### **CALCULATION OF AXISYMMETRIC FLOWS IN TURBOMACHINES, THROUGH AN EXPLICIT TIME-SPLITTING METHOD**

G. SIMANDIRAKIS, K. GIANNAKOGLU, K. ALKALAI, and K. D. PAPAILIOU (Athens, National Technical University, Greece) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1153-1158. refs  
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A formulation for the numerical solution of quasi-three dimensional viscous and inviscid flow fields is presented. This formulation is based on a fractional step numerical algorithm, while



a simple algebraic turbulence model, that of Baldwin and Lomax, is used to effect closure. Body-fitted C- and H-type grids are used for the discretization of the governing equations around blades of turbomachinery components. Author

#### A90-12623#

##### A MULTI-DOMAIN 3D EULER SOLVER FOR FLOWS IN TURBOMACHINES

A. M. VUILLOT (ONERA, Chatillon-sous-Bagneux, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1159-1168. Research supported by SNECMA. refs (ONERA, TP NO. 1989-119) Copyright

This paper describes a code for the investigation of steady inviscid compressible flows through solution of the three-dimensional Euler equations. Two main features of this code are its extended range of applications, thanks to the use of a multi-domain technique to overcome mesh difficulties, and its easiness of use. Applications to flows in turbine cascades are shown with two types of decomposition: an academical test case with a C+H two subdomain decomposition and a C+O two subdomain decomposition for a realistic geometry of a turbine stator. Author

#### A90-12624#

##### A SOLUTION ADAPTIVE FINITE ELEMENT METHOD APPLIED TO TWO-DIMENSIONAL UNSTEADY VISCOUS COMPRESSIBLE CASCADE FLOW

GUNNAR L. D. SIDEN, PER J. ALBRATEN (Volvo Flygmotor, AB, Trollhattan, Sweden), and WILLIAM N. DAWES (Cambridge University, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1169-1177. Research supported by Volvo Flygmotor, AB. refs Copyright

A method is presented for time accurate solutions of the Navier-Stokes equation on adaptively refined meshes. Turbulence is accounted for by the inclusion of a two-layer algebraic eddy viscosity model. The method is applied to two-dimensional flutter simulations in turbomachinery cascades. By considering the Navier-Stokes equations, the method is quite general in that it can handle cases ranging from the subsonic to the supersonic region. By using an adaptively refined grid, good shock resolution is achieved, which is important for correct prediction of shock/boundary layer interaction. Comparison with a linearized unsteady potential flow solver for inviscid flow and with measurements for high-speed viscous flow show promising results. However, although the computed results pick up the trends of measurements there remain quite large differences locally. This may to some extent be due to the assumption of constant interblade phase angle and amplitude, which in reality vary from blade to blade. In order to take this variation into account, the computational domain has to include more than one blade passage which rapidly increases the CPU time required. C.E.

#### A90-12625#

##### PCISM METHOD FOR TWO DIMENSIONAL COMPRESSIBLE VISCOUS CASCADE FLOW CALCULATION

LI CHENG WANG and HUI MIN ZHANG (Nanjing Aeronautical Institute, People's Republic of China) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1178-1183. Copyright

This paper is the extension of the two-dimensional subsonic viscous cascade flow field calculation. The unsteady flow equations are solved in a nonorthogonal body-fitted coordinate system using the finite difference scheme. The K-Epsilon model of turbulent flow is adopted. Numerical experiments have been carried out for the DFVLR transonic blade profile at inlet Mach numbers  $M =$

1.05 - 0.82. Comparison of the calculated results with test data is satisfactory. Author

#### A90-12635#

##### HOT WIRE MEASUREMENTS IN THE WAKE OF AN OSCILLATING AIRFOIL

A. GOULAS, H. STAPOUNTZIS (Salonika, University, Greece), N. ALBANIS, and A. CARPETIS IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1261-1268. refs Copyright

Experiments were carried out in the unsteady wake of a NACA 0015 airfoil performing sinusoidal pitching oscillations and sudden change in the angle of incidence. Large values of oscillation amplitude (15 deg) and mean angle of incidence (15 deg) were looked at. The reduced frequency was high enough (0.11) for dynamic stall phenomena to be important but not for the formation of discrete vortices. Pitching oscillations tend to delay mean-flow separation and to increase both mean and fluctuating velocities in the wake. The results are in qualitative agreement with an unsteady thin-airfoil model. For the case of the sudden change of incidence,  $u$  and  $w$  velocities are compared to those from an inviscid vortex-panel numerical model. The agreement is good to fair. Author

#### A90-12637#

##### COMPARATIVE CASCADE STUDIES OF SOME HIGH DIFFUSION COMPRESSOR BLADINGS

BHASKAR ROY, B. V. MARATHE (Indian Institute of Technology, Bombay, India), and D. B. GANGAL IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1282-1289. Research supported by the Ministry of Defence. refs Copyright

Studies of compressor blade sections have been conducted in a low-speed cascade wind tunnel at IIT Bombay to establish a method of achieving high flow turning so as to accomplish higher blade loading factor and diffusion factor without significant sacrifice in loss factor. The blade profiles tested include a basic NACA 65 series blade section with varying camber, controlled-diffusion airfoils (CDA), and an optimized tandem configuration tested with varying solidity. Results obtained indicate that CDA bladings may offer high diffusion and loading characteristics over wide range of incidences. Tandem blade cascades offer high loading and diffusion capability over positive incidence angles, but at high negative incidences the loss penalty is still high and needs further optimization studies. Author

#### A90-12639#

##### ADVERSE PRESSURE GRADIENT EFFECTS ON BOUNDARY LAYER TRANSITION IN A TURBULENT FREE STREAM

J. P. GOSTELOW (University of Technology, Sydney, Australia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1299-1306. Research supported by Rolls-Royce, PLC. refs Copyright

Measurements were made of the boundary layer transition region on a flat plate for a range of adverse pressure gradients. The experiments described were all conducted in a free stream having a grid-generated turbulence level of about 4 percent. Intermittency measurements were well represented by Narasimha's universal intermittency distribution. Interpretation of data for transition inception and completion had presented difficulties which were resolved when a consistent procedure for determination of transition inception was adopted. The transition inception Reynolds number remained reasonably constant with pressure gradient but transition lengths were significantly reduced by the imposition of even a weak adverse pressure gradient. Author

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**A90-12738\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **TURBULENT SEPARATED FLOW OVER AND DOWNSTREAM OF A TWO-ELEMENT AIRFOIL**

D. ADAIR and W. C. HORNE (NASA, Ames Research Center, Moffett Field, CA) Experiments in Fluids (ISSN 0723-4864), vol. 7, no. 8, Sept. 1989, p. 531-541. refs

Copyright

Flow characteristics in the vicinity of the flap of a single-slotted airfoil are presented and analyzed. The flow remained attached over the model surfaces, except in the vicinity of the flap trailing edge where a small region of boundary-layer separation extended over the aft 7 percent of flap chord. The airfoil configuration was tested at a Mach number of 0.09 and a chord Reynolds number of  $1.8 \times 10^6$  to the 6th in the NASA Ames Research Center 7- by 10-Foot Wind Tunnel. The flow was complicated by the presence of a strong, initially inviscid, jet, emanating from the slot between airfoil and flap, and a gradual merging of the main airfoil wake and flap suction-side boundary layer. Author

**A90-12740**

### **SURFACE ROUGHNESS EFFECT ON THE AERODYNAMIC CHARACTERISTICS OF A BLUNT BODY**

D. LEVIN (Technion - Israel Institute of Technology, Haifa) Experiments in Fluids (ISSN 0723-4864), vol. 7, no. 8, Sept. 1989, p. 566-568.

Copyright

The effect of surface roughness on the normal load characteristics of a bulb-shape configuration (representing a rotating parachute) was investigated using a solid wood model with laquer finish (basic configuration), that was modified for roughness by glueing sand paper to the conical part (treated cone) and, in the last stage, to the hemispherical part (treated cone + hemisphere). The tests were carried out, in both continuous and pitch and pose codes, in a subsonic wind tunnel; the model was mounted on a six-component sting balance located at the aft (hemispherical) part of the model. Results indicated that skin roughness affects the boundary layer and is thus associated primarily with the axial force characteristics. However, the boundary layer separation can affect the pressure distribution in a way that will influence the normal force, particularly in the case of thick configurations, as was demonstrated in the results obtained with the present model. I.S.

**A90-12783#**

### **NEW APPROACH TO SMALL TRANSONIC PERTURBATIONS FINITE ELEMENT NUMERICAL SOLVING METHOD. I - NUMERICAL DEVELOPMENTS. II - NUMERICAL APPLICATIONS**

J. J. ANGELINI and C. SOIZE (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aérospatiale (English Edition) (ISSN 0379-380X), no. 2, 1989, p. 1-41. refs

Copyright

A numerical method for solving the conservative hyperbolic equations by an implicit finite element method without artificial viscosity is described and applied to a new form of the small transonic perturbation equations. A two-dimensional code is developed and validated for the steady and unsteady cases within the limits of approximation of small transonic perturbations for the transonic and low supersonic domains. The method is robust with respect to the mesh and the choice of time step. The mesh is easily generated for complex geometries at a negligible numerical cost. The computation times are reasonable. C.D.

**A90-12784#**

### **VORTEX INTERACTIONS IN FIXED AND OSCILLATING DELTA WINGS (WATER TUNNEL VISUALIZATIONS)**

H. WERLE (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aérospatiale (English Edition) (ISSN 0379-380X), no. 2, 1989, p. 43-68. refs

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Vortex interactions that develop in wing-canard combinations in the presence of a fuselage, i.e., as they actually appear around

modern fighter planes and missiles, are experimentally studied. Using visualizations made in ONERA water tunnels, the interactions observed in the steady regime are analyzed, comparing results with and without canards for fixed models of increasing complexity, including the delta wing without fuselage, the delta wing plane with and without air intake, the delta wing missile, etc. An attempt is made to extend these results to the unsteady flow observed around the same models but subject to harmonic pitching oscillations. C.D.

**A90-12828\*#** High Technology Corp., Hampton, VA.

### **PREDICTION AND CONTROL OF TRANSITION IN SUPERSONIC AND HYPERSONIC BOUNDARY LAYERS**

MUJEEB R. MALIK (High Technology Corp., Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1487-1493. Previously cited in issue 19, p. 2941, Accession no. A87-44946. refs

(Contract NAS1-18240)

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### **A90-12835\*#** Vigyan Research Associates, Inc., Hampton, VA. **DIRECT SIMULATION OF THREE-DIMENSIONAL HYPERSONIC FLOW ABOUT INTERSECTING BLUNT WEDGES**

M. CEVDET CELENLIGIL (Vigyan Research Associates, Inc., Hampton, VA), GRAEME A. BIRD (Sydney, University, Australia), and JAMES N. MOSS (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1536-1542. Previously cited in issue 07, p. 935, Accession no. A88-22340. refs

Copyright

**A90-12838#**

### **APPLICATION OF THE HYPERSONIC ANALOGY FOR VALIDATION OF NUMERICAL SIMULATIONS**

SHMUEL EIDELMAN (Science Applications International Corp., McLean, VA) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1566-1571. Previously cited in issue 07, p. 940, Accession no. A88-22466. refs

Copyright

**A90-12839#**

### **CLOSED-FORM SOLUTIONS FOR NONLINEAR QUASI-UNSTEADY TRANSONIC AERODYNAMICS**

GABRIEL A. OYIBO (Polytechnic University, Farmingdale, NY) (International Symposium on Aeroelasticity and Structural Dynamics, 2nd, Aachen, Federal Republic of Germany, Apr. 1-3, 1985, Collected Papers, p. 71-79) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1572-1578. Previously cited in issue 14, p. 1979, Accession no. A86-33231. refs

(Contract F49620-87-C-0046; AF-AFOSR-89-0055)

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**A90-12850#**

### **SHOCK-WAVE/BOUNDARY-LAYER INTERACTION AT A SWEEP COMPRESSION CORNER**

OKTAY OZCAN and M. ORHAN KAYA (Istanbul Technical University, Turkey) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1646-1648. Research supported by the Istanbul Technical University. refs

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Results of an experimental study are reported for a supersonic flow over a swept compression corner mounted on a flat plate, where a shock wave is formed ahead of the compression corner. The adverse pressure gradient caused by the shock wave propagates upstream through the subsonic portion of the boundary layer developing over the flat plate. The interaction of the shock wave with the boundary layer can lead to flow separation if the shock wave is sufficiently strong. The study is carried out at Mach numbers between 1.8 and 2.2. The data are obtained using oil flow visualization. Besides the cylindrical and conical flow regimes previously reported by Settles and Tang (1984), a third flow regime is observed. The regime reveals itself when the Mach number

normal to the corner line is approximately one. Results of the study lend support to the 'shock detachment hypothesis'. S.A.V.

#### A90-12851#

##### CRITIQUE OF TURBULENCE MODELS FOR SHOCK-INDUCED FLOW SEPARATION

L. E. ERICSSON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1648-1650. Abridged. Previously cited in issue 20, p. 3341, Accession no. A88-48781. refs  
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#### A90-12865

##### AIRPLANE AERODYNAMICS AND PERFORMANCE

CHUAN-TAU EDWARD LAN and JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS, Roskam Aviation and Engineering Corp., 1988, 577 p. refs  
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Atmospheric properties which are important to the aeronautical engineer are outlined and airfoil theory and applications are discussed. The integrated effect of airfoils into lifting surfaces is considered as well as aircraft drag prediction. The maneuvering performance in steady symmetrical pull-ups and steady turns is studied. K.K.

#### A90-13016#

##### EXPERIMENTAL AND NUMERICAL INVESTIGATION OF VORTEX FLOW OVER A SIDESLIPPING DELTA WING

NICK G. VERHAAGEN and STEVEN H. J. NAARDING (Delft, Technische Universiteit, Netherlands) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 971-978. Previously cited in issue 16, p. 2594, Accession no. A88-40737. refs  
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#### A90-13017\*# Texas A&M Univ., College Station.

##### IN-FLIGHT BOUNDARY-LAYER TRANSITION MEASUREMENTS ON A SWEEPED WING

ANWAR AHMED (Texas A & M University, College Station), WILLIAM H. WENTZ (Wichita State University, KS), and R. NYENHUIS (Cessna Aircraft Co., Wichita, KS) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 979-985. refs  
(Contract NAG1-104)  
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Flight tests were conducted at three different altitudes to detect transition on a smoothed test region of a swept-wing business jet wing using surface hot-film sensors and sublimating chemicals. Strong influence of sweep angle on transition location was observed when the aircraft was flown at some sideslip conditions to simulate changes in effective wing sweep angle. No effects of engine noise on transition were measured when different engine power settings were used. Flight instrumentation and ground data analysis techniques are described. Correlation was obtained between the hot-film sensor signals and sublimating chemicals for transition detection. Crossflow vortices were observed for one flight condition. Results of analyzed data for various flight-test conditions are presented. Author

#### A90-13018\*# National Aeronautics and Space Administration.

##### LANGLEY RESEARCH CENTER, HAMPTON, VA.

##### NAVIER-STOKES COMPUTATIONS OF A PROLATE SPHEROID AT ANGLE OF ATTACK

VEER N. VATSA, JAMES L. THOMAS (NASA, Langley Research Center, Hampton, VA), and BRUCE W. WEDAN (Vigyan Research Associates, Inc., Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 986-993. Previously cited in issue 22, p. 3530, Accession no. A87-49626. refs  
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#### A90-13020#

##### NUMERICAL STUDY OF SINGLE IMPINGING JETS THROUGH A CROSSFLOW

J. M. M. BARATA, D. F. G. DURAO (Lisboa, Universidade Tecnica, Lisbon, Portugal), and J. J. MCGUIRK (Imperial College of Science and Technology, London, England) Journal of Aircraft (ISSN

0021-8669), vol. 26, Nov. 1989, p. 1002-1008. Previously cited in issue 09, p. 1281, Accession no. A89-25367. refs  
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#### A90-13023#

##### INVESTIGATION OF FLOW SEPARATION ON A SUPERCRITICAL AIRFOIL

B. H. K. LEE (National Research Council of Canada, Ottawa) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 1032-1037. refs  
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Transonic shock/boundary-layer interaction on the upper surface of a supercritical airfoil was investigated in the National Aeronautical Establishment High Reynolds Number Two-Dimensional Test Facility. Skin-friction coefficient measurements on the airfoil surface were carried out using a Preston tube. At the lower Mach number range of the experiments, shock-induced and trailing-edge separation regions were found to exist simultaneously. Detailed experimental measurements were carried out at  $M = 0.688$  and various values of  $\alpha$  to investigate the merging of the two separated-flow regions. Steady and unsteady pressure measurements were made for various types of shocks/boundary-layer interaction. Pressure power spectra were computed to study the characteristics of pressure fluctuations in the separated-flow regions. Fluctuating normal forces were measured for different types of flow separation, and the behavior of the unsteady load experienced by the airfoil was presented. Broadband cross-correlations of the pressure field were carried out to determine the convection velocities for attached and separated flows. Author

#### A90-13024\*# Purdue Univ., West Lafayette, IN.

##### MACH NUMBER EFFECTS ON TRANSONIC AEROELASTIC FORCES AND FLUTTER CHARACTERISTICS

ROSS W. MOHR, HENRY T. Y. YANG (Purdue University, West Lafayette, IN), and JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2, p. 749-759) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 1038-1046. Previously cited in issue 12, p. 1819, Accession no. A88-32253. refs  
(Contract NAG1-372)  
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#### A90-13025\*# Union Coll., Schenectady, NY.

##### ACCUMULATED SPAN LOADINGS OF AN ARROW WING HAVING VORTEX FLOW

C. SUBBA REDDY (Union College, Schenectady, NY) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 1047, 1048. refs  
(Contract NAS1-14193)  
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The vortex flow over an arrow wing is theoretically investigated using the free-vortex-sheet method. The sectional lift coefficient and accumulated span loadings, which are important in determining the root bending moment, are calculated. The longitudinal stability variation is also estimated. S.A.V.

#### A90-13238

##### NUMERICAL SOLUTION OF TRANSONIC FLOWS ON A STREAMFUNCTION CO-ORDINATE SYSTEM

RONALD M. BARRON and R. K. NAEEM (Windsor, University, Canada) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 9, Oct. 1989, p. 1183-1193. Research supported by NSERC. refs  
Copyright

A new method for computing steady two-dimensional full-potential transonic flow past symmetric airfoils is proposed which uses von Mises variables  $\chi$  and  $\psi$  (where  $\psi$  is taken as the streamfunction of the flow). The flow equations are transformed into the von Mises variables and solved subject to appropriate boundary conditions for a class of transonic flows over symmetric airfoils. The class considered is that for which the

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flow is isentropic or irrotational. The computed results for subcritical and supercritical cases are in good agreement with the available data. V.L.

**N90-10003#** National Aerospace Lab., Tokyo (Japan).  
**A NUMERICAL METHOD FOR SOLVING TRANSONIC FLOW PAST AIRCRAFT IN CARTESIAN COORDINATES**  
MASAYOSHI NAKAMURA Dec. 1988 30 p In JAPANESE;  
ENGLISH summary  
(NAL-TR-1008; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

A numerical method for computing inviscid transonic flow around an arbitrary aircraft configuration is described. The basic formula consists of simultaneous equations for variables of velocity potential and Mach number. This formula is a permutation of the full potential equation. The simultaneous equations are solved numerically, satisfying given boundary conditions. The shock wave is captured as a discontinuous surface where the flow conditions satisfy the shock wave relationship. The calculation flow field is a rectangular box field. Grid points and boundary points are generated in Cartesian coordinates. The grid points are equidistant but their intervals can be varied with the location. External forms of the aircraft and vortex sheets are shaped from numerous small triangular planes. The majority of the boundary points are on these external forms. The basic formula is expressed as difference equations using the grid points and the boundary points. The difference equations are solved in the numerical procedure. Several calculated results of this method are compared with the experimental and other numerical results. Author

**N90-10004\*#** Sverdrup Technology, Inc., Cleveland, OH.  
**A SUPERSONIC THROUGH-FLOW FAN ENGINE AIRFRAME INTEGRATION STUDY Final Report**  
PAUL J. BARNHART Sep. 1989 11 p Presented at the Aircraft Design, Systems and Operations Conference, Seattle, WA, 31 Jul. - 2 Aug. 1989; cosponsored by AIAA, AHS, and ASEE (Contract NAS3-25266)  
(NASA-CR-185140; E-5068; NAS 1.26:185140; AIAA-89-2140)  
Avail: NTIS HC A03/MF A01 CSCL 01/1

Engine airframe integration effects are investigated for supersonic through-flow fan engines installed on a Mach 3.20 supersonic cruise vehicle. Six different supersonic through-flow fan engine installations covering the effects of engine size, nacelle contour, nacelle placement, and approximate bypass plume effects are presented. The different supersonic through-flow fan installations are compared with a conventional turbine bypass engine configuration on the same basic airframe. The supersonic through-flow fan engine integrations are shown to be comparable to the turbine bypass engine configuration on the basis of installed nacelle wave drag. The supersonic through-flow fan engine airframe integrated vehicles have superior aerodynamic performance on the basis of maximum lift-to-drag ratio than the turbine bypass engine installation over the entire operating Mach number range from 1.10 to 3.20. When approximate bypass plume modeling is included, the supersonic through-flow fan engine configuration shows even larger improvements over the turbine bypass engine configuration. Author

**N90-10005** Mississippi State Univ., State College.  
**THREE-DIMENSIONAL UNSTEADY TRANSONIC VISCOUS-INVISCID INTERACTION Ph.D. Thesis**  
SHAHYAR PIRZADEH 1988 114 p  
Avail: Univ. Microfilms Order No. DA8909851

The objective of this study is the development of a numerical technique which can provide three-dimensional, time-accurate, compressible, turbulent flow solutions in a practical and relatively economical way. The approach taken is that of the method of viscous-inviscid interaction. The Euler equations are assumed to govern the outer inviscid portion of the flow, and the viscous layer close to the solid wall is described by a set of integral boundary-layer equations. The viscous solutions are obtained in a direct fashion with a weighted-average phase error scheme. The discretized integral form of the Euler equations are solved with an upwind, finite-volume scheme. The method of equivalent sources

is used for viscous-inviscid coupling. Steady-state and unsteady computations for two AGARD airfoils and a wing show that satisfactory engineering solutions can be obtained for attached, high Reynolds number flows using this method. Quasi-unsteady interactions are shown to produce similar results to those provided by true-unsteady interactions. Considerable computer resources can be saved for some cases by using quasi-unsteady interactions. Dissert. Abstr.

**N90-10006\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.  
**AN INTEGRATED CFD/EXPERIMENTAL ANALYSIS OF AERODYNAMIC FORCES AND MOMENTS**  
JOHN E. MELTON, DAVID D. ROBERTSON, and SETH A. MOYER Aug. 1989 52 p  
(NASA-TM-102195; A-89145; NAS 1.15:102195) Avail: NTIS HC A04/MF A01 CSCL 01/1

Aerodynamic analysis using computational fluid dynamics (CFD) is most fruitful when it is combined with a thorough program of wind tunnel testing. The understanding of aerodynamic phenomena is enhanced by the synergistic use of both analysis methods. A technique is described for an integrated approach to determining the forces and moments acting on a wind tunnel model by using a combination of experimentally measured pressures and CFD predictions. The CFD code used was FLO57 (an Euler solver) and the wind tunnel model was a heavily instrumented delta wing with 62.5 deg of leading-edge sweep. A thorough comparison of the CFD results and the experimental data is presented for surface pressure distributions and longitudinal forces and moments. The experimental pressures were also integrated over the surface of the model and the resulting forces and moments are compared to the CFD and wind tunnel results. The accurate determination of various drag increments via the combined use of the CFD and experimental pressures is presented in detail. Author

**N90-10008#** Florida Agricultural and Mechanical Univ., Tallahassee. Fluid Mechanics Research Lab.  
**BASIC STUDIES OF THE UNSTEADY FLOW PAST HIGH ANGLE OF ATTACK AIRFOILS Final Report, 1 Oct. 1986 - 30 Oct. 1988**  
ANJANEYULU KROTHAPALLI, LUIZ LOURENCO, and LEON VANDOMMELEN 15 May 1989 132 p  
(Contract AF-AFOSR-0243-86; AF PROJ. 2307)  
(AD-A210252; AFOSR-89-0780TR) Avail: NTIS HC A07/MF A01 CSCL 20/4

Experimental and numerical simulations have been carried out to study the unsteady flow past an impulsively started NACA 0012 airfoil at different angles of attack. A novel experimental technique, commonly referred to as particle image displacement velocimetry (PIDV), is successfully implemented to measure the instantaneous velocity fields. The velocity field is measured with sufficient accuracy so that the distribution of vorticity can be calculated. The unsteady separated flow fields generated by these airfoils contain large scale vortical structures such as a primary vortex generated at the leading edge of the airfoil with secondary vortices upstream of it, a trailing vortex, and a vortex sheet type structure. The origins and time evolution of these structures are clearly depicted by the instantaneous velocity and vorticity fields. A random-walk vortex simulation of the full Navier-Stokes equations were performed as a comparison. GRA

**N90-10009#** Mississippi State Univ., Mississippi State. Dept. of Aerospace Engineering.  
**COMPUTATION OF TRANSONIC FLOW ABOUT STORES Final Report, Jun. 1984 - Sep. 1988**  
DAVID L. WHITFIELD and JOE F. THOMPSON Jun. 1989 56 p  
(Contract F08635-84-C-0228; AF PROJ. 2307)  
(AD-A210402; AD-E801954; AFATL-TR-89-20) Avail: NTIS HC A04/MF A01 CSCL 01/1

The objective of this program was to derive grid generation and fluid flow algorithms to predict the aerodynamics of aircraft/weapon configurations. Both captive carriage and the

launch transient mode were considered in the design of the methods. The numerical grid generation techniques developed were both algebraic, based on transfinite interpolation, and elliptic, based on iterative solution of partial differential equations. The techniques were incorporated into one code that became the numerical grid generation for the Eglin Arbitrary Geometry Implicit Euler (EAGLE) code. In addition, an adaptive version of the grid generation code was developed and applied to missile configurations. The flow solvers developed were all upwind, finite volume schemes ranging from explicit, split flux vector to implicit, split flux difference algorithms. Both steady and unsteady, Euler and Navier-Stokes, were written and applied to various configurations. Two implicit algorithms were employed to form the EAGLE flow solver code. This code was run on complex aircraft/weapon configurations, including the launch transient problem of a weapon releasing from an aircraft pylon. GRA

**N90-10010#** Calspan Corp., Arnold AFS, TN.  
**WIND TUNNEL SUPPORT SYSTEM EFFECTS ON A FIGHTER AIRCRAFT MODEL AT MACH NUMBERS FROM 0.6 TO 2.0**

**Final Report, 23 Aug. - 1 Dec. 1988**

DAVID G. WHITBY Jul. 1989 63 p Prepared in cooperation with AEDC, Arnold AFS, TN  
 (AD-A210614; AEDC-TR-89-4) Avail: NTIS HC A04/MF A01 CSCL 14/2

A wind tunnel investigation was conducted using a fighter aircraft model with various sting and blade support system arrangements to evaluate the effects of the model support system on the total body and component longitudinal force and moment data. Total aerodynamic force and moment data were determined from corrected strain-gage balance measured loads. Component data (i.e., tail loads) were obtained by subtracting tail-off balance data from tail-on data. Data taken at free-stream Mach numbers from 0.6 to 2.0 and model angles of attack from -2 to 8 deg were examined. The analysis indicates a significant change in total body and component force coefficients in the presence of various support system configurations. The upper blade tends to decrease drag, lift, and pitching-moment coefficients, while the lower blade generally increases these coefficients. The influence of the sting on aerodynamic coefficients is a function of Mach number and angle of attack. A correction methodology using sting/blade tares is proposed and evaluated. GRA

**N90-10012#** Rockwell International Science Center, Thousand Oaks, CA.

**SUPERSONIC FLOW COMPUTATIONS OVER AEROSPACE CONFIGURATIONS USING AN EULER MARCHING SOLVER**  
 KUO-YEN SZEMA, SUKUMAR CHAKRAVARTHY, and VIJAYA SHANKAR Washington Jul. 1987 49 p  
 (Contract NAS1-15820)  
 (NASA-CR-4085; NAS 1.26:4085) Avail: NTIS HC A03/MF A01 CSCL 01/1

For fully supersonic flows, an efficient strategy for obtaining numerical solutions is to employ space marching techniques. A full potential marching technique, known as the SIMP code and capable of handling such embedded subsonic regions, has achieved some success analyzing low supersonic Mach number flows. The extension of the full potential approach to the Euler equation which model the exact nonlinear inviscid gas dynamic flow processes is presented. Within the assumption of an inviscid flow, such an Euler marching solver can be applied to a wide class of shocked flows including the hypersonic range. The intent is to maintain some of the basic features of the full potential SIMP code within the Euler solver in dealing with geometry input, gridding techniques, and input/output routines including post processing of results. An Euler marching code known as EMTAC was developed. Results obtained for a variety of configurations involving canard, wing, horizontal tail, flow-through inlet, and fuselage using both the EMTAC and SIMP codes are reported. For shocked cases satisfying the isentropic assumption, the EMTAC and SIMP codes produced practically the same results. In terms of execution time, the EMTAC code is slower. Author

**N90-10361#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**DIRECT NUMERICAL STUDY OF LEADING-EDGE CONTAMINATION**

P. R. SPALART /In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 13 p Apr. 1989  
 Copyright Avail: NTIS HC A18/MF A01 CSCL 01/1

Instability, turbulence, and relaminarization in the attachment-line region of swept and unswept cylindrical bodies are studied by numerical solution of the full Navier-Stokes equations. The flow is simulated over a strip containing the attachment-line and treated as homogeneous in the spanwise direction; the disturbances decay exponentially upstream. Transpiration through the wall may be prescribed. The new method, which admits completely general disturbance, agrees with published linear-stability results, which were limited to an apparently restrictive form of disturbance. Fully developed turbulent solutions with sweep are generated and compare well with the experiment. The turbulence is subcritical (except for blowing), resulting in large hysteresis loops. By lowering the sweep Reynolds number, or increasing the suction, the turbulent flow is made to relaminarize. The relaminarization Reynolds number is much less sensitive to suction than the linear-stability Reynolds number. Extensive attempts to detect the postulated nonlinear instability of the unswept flow failed, suggesting that this flow is linearly and nonlinearly stable. Author

**N90-10364#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**GOERTLER INSTABILITY ON AN AIRFOIL: COMPARISON OF MARCHING SOLUTION WITH EXPERIMENTAL OBSERVATIONS**

VIJAY KALBURGI, SIVA M. MANGALAM (Analytical Services and Materials, Inc., Hampton, VA.), and J. RAY DAGENHART /In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 16 p Apr. 1989  
 Copyright Avail: NTIS HC A18/MF A01 CSCL 01/1

Theoretical predictions based on the marching technique are compared with experimental observations on an airfoil with a concave region. Theoretical predictions of the wavelength of the most amplified Goertler vortex are in excellent agreement with the experimental observation for the range of chord Reynolds numbers from 1.0 to 3.67 million. In the convex zone, solutions from the marching technique showed that the initial counter-rotating vortex pairs lift off the surface and dissipate while another layer of vortex pairs of opposite rotation develops near the surface. This confirms the experimentally observed double peaked streamwise velocity perturbations. Furthermore, the streamwise velocity perturbations which dominate spanwise variation in the surface shear stress distribution shift by half a wavelength in the convex region. The experimental flow visualization photographs clearly confirm this phenomena. Author

**N90-10367#** Bristol Univ. (England). Dept. of Aerospace Engineering.

**THE THREE-DIMENSIONAL VORTEX SHEET STRUCTURE ON DELTA WINGS**

MARTIN V. LOWSON /In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 16 p Apr. 1989  
 Copyright Avail: NTIS HC A18/MF A01

Preliminary results are reported from flow visualization studies of the separated shear layers on slender delta wings in air at Reynolds numbers from 3000 to 100,000 based on chord. The work confirms the existence of a systematic structure in the shear layer paralleling the classic instabilities occurring in other cases. Both quasi two-dimensional instabilities traveling at mean flow velocities and a new form of streamwise instability, believed to result from curvature of the vortex sheet, were identified. Both instabilities are found to be stabilized by the stretching process towards the center of the core. For the case studied the interaction between the two instabilities causes the vortex sheet to become turbulent at Reynolds numbers above 20,000 based on local chord.

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Forced response studies of the vortex sheet have demonstrated the existence of new mechanisms for vortex formation in the shear layer. The results are believed to be relevant to more complex three dimensional shear layers, and have implications for full scale flows on aircraft at high angles of attack. Author

**N90-10373#** California State Univ., Long Beach. Dept. of Aerospace Engineering.

### **A THREE-DIMENSIONAL LINEAR STABILITY APPROACH TO TRANSITION ON WINGS AT INCIDENCE**

TUNCER CEBECI, H. H. CHEN, and D. ARNAL /in AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 13 p Apr. 1989 Sponsored in part by Navy Copyright Avail: NTIS HC A18/MF A01

The calculation of transition of an infinite swept wing was investigated for a range of sweep angles, Reynolds numbers, and angles of attack. The method solves boundary layer and Orr-Sommerfeld equations by a finite-difference procedure and involves interaction with the inviscid flow. Amplification rates in the  $e$  (sup  $n$ ) method are determined with an eigenvalue procedure which determines the relationship between the wave numbers. The calculation method is evaluated in terms of measurements reported for the flow around an ONERA-D wing equipped with a cambered leading edge and attached to a half fuselage. It is shown to be convenient to use, particularly because the neutral stability curves (zarfs) facilitate the calculation and avoid uncertainties associated with the choice of magnitude and location of the critical frequencies. In general, the calculated values of the onset of transition are in good agreement with measured values, for the eight cases examined. Author

**N90-10380#** National Aerospace Lab., Amsterdam (Netherlands). GARTEUR Action Group AD.

### **A EUROPEAN COLLABORATIVE INVESTIGATION OF THE THREE-DIMENSIONAL TURBULENT SHEAR LAYERS OF A SWEPT WING**

B. VANDENBERG /in AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 19 p Apr. 1989 Copyright Avail: NTIS HC A18/MF A01

The turbulent shear layers of a swept wing are described. The measurements will comprise both the upper and lower wing boundary layer, as well as, the three-dimensional near-wake behind the wing. Starting from required viscous flow properties, a wing geometry was designed by flow calculations. The theoretical wing design was checked by pilot model tests. The results suggest that the viscous flow may become an interesting test case for turbulence models for three-dimensional shear flows. The measurements in the turbulent shear layers will comprise mean flow quantities, skin friction data, and the six Reynolds stress tensor components. To establish the measurement accuracy, several data checks will be performed, including independent tests with similar models in two different wind tunnels. Author

**N90-10829\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **MEASUREMENTS OF PRESSURES ON THE TAIL AND AFT FUSELAGE OF AN AIRPLANE MODEL DURING ROTARY MOTIONS AT SPIN ATTITUDES**

JAMES S. BOWMAN, JR., RANDY S. HULTBERG, and COLIN A. MARTIN (Aeronautical Research Labs., Melbourne, Australia) Washington Nov. 1989 85 p (NASA-TP-2939; L-16570; NAS 1.60:2939) Avail: NTIS HC A05/MF A01 CSCL 01/1

An investigation was conducted in the Langley Spin Tunnel to measure the pressures on the surface of the horizontal and vertical tail and the aft fuselage of an aircraft model. The pressures were measured on a model of a proposed Australian Primary Trainer airplane configuration while the model was rotating at spinning attitudes. The test results indicate that the presence of the horizontal tail adversely modifies the surface pressure on the vertical tail. The presence of the wing also adversely modifies the pressures on the horizontal and vertical tails. Author

**N90-10830\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **LOW-SPEED, HIGH-LIFT AERODYNAMIC CHARACTERISTICS OF SLENDER, HYPERSONIC ACCELERATOR-TYPE CONFIGURATIONS**

GREGORY M. GATLIN Washington Nov. 1989 46 p (NASA-TP-2945; L-16537; NAS 1.60:2945) Avail: NTIS HC A03/MF A01 CSCL 01/1

Two investigations were conducted in the Langley 14 by 22 Foot Subsonic Tunnel to determine the low-speed aerodynamic characteristics of a generic hypersonic accelerator-type configuration. The model was a delta wing configuration incorporating a conical forebody, a simulated wrap-around engine package, and a truncated conical aftbody. Six-component force and moment data were obtained over a range of attack from -4 to 30 degrees and for a sideslip range of + or - 20 degrees. In addition to tests of the basic configuration, component build-up tests were conducted; and the effects of power, forebody nose geometry, canard surfaces, fuselage strakes, and engines on the lower surface alone were also determined. Control power available from deflections of wing flaps and aftbody flaps was also investigated and found to be significantly increased during power-on conditions. Large yawing moments resulted from asymmetric flow fields exhibited by the forebody as revealed by both surface pressure data and flow visualization. Increasing nose bluntness reduced the yawing-moment asymmetry, and the addition of a canard eliminated the yawing-moment asymmetry. Author

### **N90-10831** Illinois Univ. at Urbana-Champaign, Savoy. NUMERICAL SIMULATION OF LEADING-EDGE VORTEX ROLLUP AND BURSTING Ph.D. Thesis

STEVEN ALLAN BRANDT 1988 117 p Avail: Univ. Microfilms Order No. DA8908627

Vortex aerodynamics has played an important role in the development of high performance aircraft in recent years. Although computer codes which solve the 3-D Euler equations have been used extensively to study vortex flows they don't include physical viscosity effects associated with vortex flows. The Euler solvers do, however, contain numerical viscosity. As a result, viscosity effects in the Euler solutions such as vortex core size, vortex burst location, leading edge separation, and vortex rollup often do not agree quantitatively with results of physical experiments. Models are defined for these physical viscosity effects which can be coupled with an Euler solver to improve modeling of vortex physics. A vortex core model is derived from the steady, incompressible Navier-Stokes equations written in cylindrical coordinates. The core model is coupled with an Euler solver and tested on a variety of delta wings over a range of angles of attack. The resulting surface pressure distributions and vortex burst locations are shown to be much closer to wind tunnel data and results from Navier-Stokes solutions than results from Euler codes alone. A second model is defined for viscosity effects in the viscous shear layer near the rounded leading edge of a highly swept wing based on an analogy to the boundary layer on a flat plate. The model is incorporated into an Euler code through the surface boundary condition and source terms in the boundary cells. The modified code is tested on several highly swept wings with rounded leading edges. Results are also shown to be in closer agreement with wind tunnel data for the same wing geometry than results from an unmodified Euler code. Dissert. Abstr.

**N90-10833\*#** Institute for Computer Applications in Science and Engineering, Hampton, VA.

### **LINEAR INSTABILITY OF SUPERSONIC PLANE WAKES Final Report**

D. T. PAPAGEORGIOU (City Coll. of the City Univ. of New York, NY.) Sep. 1989 48 p Submitted for publication (Contract NAS1-18605) (NASA-CR-181911; ICASE-89-66; NAS 1.26:181911) Avail: NTIS HC A03/MF A01 CSCL 01/1

In this paper we present a theoretical and numerical study of the growth of linear disturbances in the high-Reynolds-number and laminar compressible wake behind a flat plate which is aligned



with a uniform stream. No ad hoc assumptions are made as to the nature of the undisturbed flow (in contrast to previous investigations) but instead the theory is developed rationally by use of proper wake-profiles which satisfy the steady equations of motion. The initial growth of near wake perturbation is governed by the compressible Rayleigh equation which is studied analytically for long- and short-waves. These solutions emphasize the asymptotic structures involved and provide a rational basis for a nonlinear development. The evolution of arbitrary wavelength perturbations is addressed numerically and spatial stability solutions are presented that account for the relative importance of the different physical mechanisms present, such as three-dimensionality, increasing Mach numbers enough (subsonic) Mach numbers, there exists a region of absolute instability very close to the trailing-edge with the majority of the wake being convectively unstable. At higher Mach numbers (but still not large-hypersonic) the absolute instability region seems to disappear and the maximum available growth-rates decrease considerably. Three-dimensional perturbations provide the highest spatial growth-rates. Author

**N90-10834\*#** Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.

**AN EXPERIMENTAL INVESTIGATION OF THE AERODYNAMIC CHARACTERISTICS OF SLANTED BASE OGIVE CYLINDERS USING MAGNETIC SUSPENSION TECHNOLOGY**

CHARLES W. ALCORN and COLIN BRITCHER Nov. 1988 90 p  
(Contract NAG1-716)  
(NASA-CR-181708; NAS 1.26:181708) Avail: NTIS HC A05/MF A01 CSDL 01/1

An experimental investigation is reported on slanted base ogive cylinders at zero incidence. The Mach number range is 0.05 to 0.3. All flow disturbances associated with wind tunnel supports are eliminated in this investigation by magnetically suspending the wind tunnel models. The sudden and drastic changes in the lift, pitching moment, and drag for a slight change in base slant angle are reported. Flow visualization with liquid crystals and oil is used to observe base flow patterns, which are responsible for the sudden changes in aerodynamic characteristics. Hysteretic effects in base flow pattern changes are present in this investigation and are reported. The effect of a wire support attachment on the 0 deg slanted base model is studied. Computational drag and transition location results using VSAERO and SANDRAG are presented and compared with experimental results. Base pressure measurements over the slanted bases are made with an onboard pressure transducer using remote data telemetry. Author

**N90-10837** Purdue Univ., West Lafayette, IN.  
**FREQUENCY DOMAIN AERODYNAMIC ANALYSIS OF INTERACTING ROTATING SYSTEMS Ph.D. Thesis**

JINSOO CHO 1988 135 p  
Avail: Univ. Microfilms Order No. DA8911891

A multiple harmonic, frequency domain panel method based on linear compressible aerodynamic theory is developed for the aerodynamic analysis of interacting rotating systems. Each stage of the iteration involves the solution of an isolated propeller or wing problem, the interaction being done through the Fourier transform of the induced velocity field. The method was validated by comparing the predicted velocity field about an isolated propeller with detailed laser Doppler velocimeter measurements. The unsteady aerodynamic coupling between a propeller and a wing is analyzed. The mean loads are compared with the measured data and comparisons were made between the fluctuating loads predicted by the present method and a quasi-steady vortex lattice scheme. Also a counter rotating propeller system was investigated. The mean performance parameters are compared with measured data, and the predicted velocity field with detailed laser Doppler velocimeter measurements. Comparisons were also made between the fluctuating loads predicted by the present method and a time domain panel method. Dissert. Abstr.

**N90-10838** Tennessee Univ., Knoxville.

**A SCALAR/VECTOR POTENTIAL SOLUTION FOR AERODYNAMIC COEFFICIENTS IN WIND SHEAR Ph.D. Thesis**

JYH-CHYANG ALEX WANG 1988 227 p  
Avail: Univ. Microfilms Order No. DA8911769

A recent innovation in aerodynamic calculation techniques is a formulation for the velocity field based on scalar and vector potentials. This technique is presented and implemented into the panel method such that it is able to solve not only irrotational flow but also rotational flow. The application of interest is to two-dimensional airfoils moving into a nonuniform approach flow. Comparisons with theoretical and numerical results are included. Furthermore, the variations of lift and moment coefficients of quasi-steady simulated flight of an airfoil through JAWS wind shear are also studied. Although the present study does demonstrate the hazard of microbursts, the indicated wind shear effects on aerodynamic coefficients are not as great as expected. The present method only indicates the decrease of the effective angle of attack as an important factor. However, in a wind field with intense downdrafts, viscous effects and flow separation should also be crucial. Although the present inviscid model has shown great advantages as a preliminary study of the wind shear effects on aerodynamic coefficients, it cannot predict viscous effects and flow separation phenomena. Therefore, further investigation is recommended to implement viscous effects. For potential flow calculations, comparable accuracy to that obtainable from higher-order panel methods can be achieved by the present formulation using the same number of control points. The present conceptual split of the onset flow into two components,  $V_{\text{sub } 0 \text{ normal}}$  and  $V_{\text{sub } 0 \text{ tangential}}$  to the zero lift line, is new. The proper vorticity distribution can be determined from  $-V_{\text{sub } 0 \text{ normal}}$  directly without imposing an artificial vorticity distributor. This split also supplies a numerically superior form for the Neumann-type lower-order formulation. Author

## 03

## AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

**A90-10264**

**PRE-ESCAPE AND ESCAPE AIRCRAFT MANEUVERS AND GYRATIONS - A CRITICAL UNDER-REPORTED PROBLEM AFFECTING ESCAPE SYSTEM PERFORMANCE AND AIRCREW SAFETY**

FREDERICK C. GUILL (U.S. Navy, Naval Air Systems Command, Washington, DC) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, Oct. 1989, Section II, p. B11-B23. Copyright

An examination of the records of a large number of post-1968 aircraft mishaps involving unusual serious injuries revealed that, in an large percentage of the cases, the mishap records failed to report the aircraft maneuvering and gyrations before and during crew escape. It is shown that, in many instances, these maneuvers might have caused the aircrew to be extremely malpositioned for the initial boost stroke or have tumbled the seat as it separated from the aircraft, increasing the susceptibility to injury or causing it. This paper reports the findings obtained by comparing the Medical Officer's Reports/Flight Surgeon's Reports computer runs against the original records, discusses the physical nature of the problems caused by aircraft maneuvering and/or gyrations during the escape, provides an explanation for these discrepancies in reporting, and suggests ways of reducing the magnitude of the reporting problem. The importance of thoroughly completing the aircraft mishap investigation report form is emphasized. I.S.

### 03 AIR TRANSPORTATION AND SAFETY

**A90-10265**

**HELICOPTER WIRE STRIKE ACCIDENT AND HIGH VOLTAGE ELECTROCUTION - A CASE REPORT**

D. M. POSEY, G. N. WAGNER, S. E. MCMILLIN, C. J. RUEHLE, B. E. SCHELL (Armed Forces Institute of Pathology, Washington, DC) et al. *Aviation, Space, and Environmental Medicine* (ISSN 0095-6562), vol. 60, Oct. 1989, Section II, p. B29-B34. refs  
Copyright

Helicopter wire-strike accidents usually involve high-voltage lines or telephone wires where the resulting impact is low velocity with minimal loss of occupiable space. Death and injury in these mishaps is often due to blunt force trauma to the head. In a recent wire strike accident investigated by the Division of Aerospace Pathology at The Armed Forces Institute of Pathology, the circumstances suggest that death of both aviators was due to high-voltage electrocution. Evidence surrounding the case and high-voltage electrocution are discussed. Author

**A90-10266**

**FIRE DEATHS IN AIRCRAFT WITHOUT THE CRASHWORTHY FUEL SYSTEM**

CHARLES S. SPRINGATE, ROBERT R. MCMEEKIN, and CHARLES J. RUEHLE (U.S. Armed Forces Institute of Pathology, Washington, DC) *Aviation, Space, and Environmental Medicine* (ISSN 0095-6562), vol. 60, Oct. 1989, Section II, p. B35-B38. refs

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Cases reported to the Armed Forces Institute of Pathology were examined for occupants of the helicopters without the crashworthy fuel system (CWFS) who survived crashes but died as a result of postcrash fires. There were 16 fire deaths in the 9 such accidents which occurred between January 1976 and April 1984. All of these victims would have survived if there had been no postcrash fire. Partial body destruction by fire probably prevented inclusion of many other cases. The dramatic reduction in fire deaths and injuries due to installation of the CWFS in Army helicopters is discussed. It is concluded that fire deaths and injuries in aircraft accidents could almost be eliminated by fitting current and future aircraft with the CWFS. Author

**A90-10269**

**THE USE OF SOOT ANALYSIS AS AN INVESTIGATIVE TOOL IN AIRCRAFT FIRES**

MERRITT M. BIRKY (National Transportation Safety Board, Washington, DC) and KENT J. VOORHEES (Colorado School of Mines, Golden) *Aviation, Space, and Environmental Medicine* (ISSN 0095-6562), vol. 60, Oct. 1989, Section II, p. B72-B77. refs

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This paper describes the techniques that were applied in the investigation of fire deaths in a hotel, to illustrate how such techniques can be used in the identification of the materials that burned and the toxic products formed in aircraft accident investigations. It is recommended that, in the future, the computer-interfaced mass spectrometer analysis should be done on the soot collected from the respiratory tract of fire victims involved in aircraft accidents as a means for determining the type of products inhaled and the source of the toxic products, as well as the relative time of postcrash survival. This information can be used to support the carboxyhemoglobin and other toxicologic and pathologic determinations. I.S.

**A90-11002#**

**EFFECTS OF RANDOM INITIAL CONDITIONS AND DETERMINISTIC WINDS ON SIMULATED PARACHUTE MOTION**

GUIDO DE MATTEIS and LUCIANO M. DE SOCIO (Roma I, Università, Rome, Italy) *Journal of Aircraft* (ISSN 0021-8669), vol. 26, Oct. 1989, p. 900-906. Research supported by MPI. refs  
Copyright

The effect of some random perturbations in the initial conditions on the gliding motion of a parachute are studied. Small and large perturbations of the initial pitch angle in the absence of wind are

analyzed. It is shown how large perturbations of low probability significantly influence the motion of parachutes that meet a longitudinal stability criterion. Periodic horizontal wind effects on stable parachutes were analyzed as well. K.K.

**A90-11155#**

**ELECTROMAGNETIC CHARACTERIZATION OF LIGHTNING ON AIRCRAFT [CARACTERISATION ELECTROMAGNETIQUE DU FOUDROIEMENT D'UN AERONEF]**

J. P. MOREAU, F. ISSAC (ONERA, Chatillon-sous-Bagneux, France), and J. Y. JOUAN (Thomson-CSF, Division Cimsa-Sintra, Arcueil, France) (Colloque sur la Compatibilite Electromagnetique, 5th, Evian, France, Sept. 12-14, 1989) ONERA, TP no. 1989-131, 1989, 7 p. In French. Research supported by DRET. refs  
(ONERA, TP NO. 1989-131)

The instrumentation of the Transall aircraft is described, and measurements of the electromagnetic characteristics of lightning are presented. The aircraft has sensors for the measurement of impact current at four locations and for the measurement of electric fields at seven locations. The pass band of the sensor extends from 0.5 to 5 MHz, enabling high-resolution data to be obtained of the low-frequency electric field. Other data obtained include magnetic field measurements with a low-frequency cutoff of 100 Hz, magnetic field measurements obtained in the fuselage, and video images obtained at 200 images/sec. The results are discussed with respect to both the source of the disturbance and the nature of the lightning phenomena. R.R.

**A90-11157#**

**EXPERIMENTAL-THEORETICAL COMPARISON FOR CURRENT INJECTION ON AN AIRCRAFT MODEL [COMPARAISON EXPERIENCE-CALCUL POUR UNE INJECTION DE COURANT SUR MAQUETTE D'AVION]**

J. C. ALLIOT, J. GRANDO, G. LABAUNE, and F. ISSAC (ONERA, Chatillon-sous-Bagneux, France) (Colloque sur la Compatibilite Electromagnetique, 5th, Evian, France, Sept. 12-14, 1989) ONERA, TP no. 1989-133, 1989, 10 p. In French. refs  
(ONERA, TP NO. 1989-133)

Laboratory measurements of electromagnetic fields on a model of a Transall C160 aircraft subjected to transient current injection have been compared with theoretical results obtained using the three-dimensional finite difference code, ALICE, developed to analyze the aircraft-lightning interaction. Good agreement with respect to the form and amplitude of signals is obtained for two configurations of current entrance and exit locations. A numerical model of aircraft lightning is discussed which was developed based on data obtained in 1988 on the Transall aircraft. R.R.

**A90-11164#**

**TRANSALL 88 - LIGHTNING CHARACTERIZATION PROGRAM**

J. P. MOREAU, J. Y. JOUAN, and F. ISSAC (ONERA, Chatillon-sous-Bagneux, France) (International Aerospace and Ground Conference on Lightning and Static Electricity, Bath, England, Sept. 26-28, 1989) ONERA, TP no. 1989-142, 1989, 8 p. refs  
(ONERA, TP NO. 1989-142)

ONERA has performed during the year 1988 a complete airborne lightning characterization program, including sensors design, instrumentation layout, extensive ground test of the whole aircraft set in a coaxial return path, and inflight measurements. The two main purposes of this program were, first, to derive an understanding of the discharge evolution from simultaneous data collected on various locations of the aircraft and, second, to increase and improve the already available set of data collected by the previous programs (Transall, CV-580, F106). This paper gives the main characteristics of the instrumentation followed by a description of the results divided in two parts, one dedicated to the results as they were available in previous programs, and one dedicated to data which are only available in the Transall 88 program. It is shown how this unique set of data can be used to validate the hypothesis suggested in the past about the lightning/aircraft connection processes. Author



**A90-11170#****ELECTROSTATIC FIELD CONDITIONS ON AN AIRCRAFT STRICKEN BY LIGHTNING**

P. LAROCHE, A. DELANNOY (ONERA, Chatillon-sous-Bagneux, France), and H. LE COURT DE BERU (ECOPOL, Paris, France) (International Aerospace and Ground Conference on Lightning and Static Electricity, Bath, England, Sept. 26-28, 1989) ONERA, TP no. 1989-148, 1989, 9 p. Research supported by DRET. refs (ONERA, TP NO. 1989-148)

Results of in-flight lightning strike experiments performed in 1985 with the Convair CV 580 aircraft and in 1988 with the Transall C 160 aircraft are discussed in terms of onset conditions and aircraft size influences. Electrostatic field sensors are used to measure values of the field in different places of the airframe just before and after a lightning strike, from which the corresponding atmospheric field and aircraft potential are derived. The size of the aircraft does not seem to play a part in the characteristics of the ignition condition. Lightning occurs in moderate atmospheric field conditions corresponding to a mean horizontal field of about 40 kV/m. The mean local potential of the two aircraft is close to -1 MV before strike, but this parameter seems to be nothing but a consequence of triboelectricity and induced corona. C.E.

**A90-11171#****ELECTROSTATIC DESCRIPTION OF A POSITIVE LEADER IGNITION FROM AN AIRCRAFT**

G. LABAUNE, J. P. APARICIO, A. DELANNOY, F. ISSAC, J. C. ALLIOT (ONERA, Chatillon-sous-Bagneux, France) et al. (International Aerospace and Ground Conference on Lightning and Static Electricity, Bath, England, Sept. 26-28, 1989) ONERA, TP no. 1989-149, 1989, 5 p. Research supported by DRET. refs (ONERA, TP NO. 1989-149)

Laboratory experiments have shown that positive streamers have two important macroscopic physical properties. Assuming these two properties (electric field is a constant in the medium, and the charge removed before the leader ignition is a constant) are still true in the case of positive streamers developed around an aircraft at the beginning of the connection with a lightning discharge, a relation is derived between the size of the aircraft and the atmospheric electric field which is needed for the ignition of a positive leader from the aircraft. Author

**A90-11437****THEORETICAL ANALYSIS OF AN ICING TEST APPARATUS FOR TURBINE ENGINE AIR INTAKES [ANALYSE THEORIQUE D'UN DISPOSITIF D'ESSAIS EN GIVRAGE POUR ENTREES D'AIR DE MOTEUR A TURBINE]**

PASCAL PREL (Aerospatiale, Division Avions, Toulouse, France) AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 23 p. In French. (AAAF PAPER NT 88-20) Copyright

A theoretical analysis of icing in turbine engine air intakes is presented, comparing aerodynamic fields and water drop trajectories obtained in flight with those obtained in an icing wind tunnel. In the present study, aerodynamic fields are analyzed using an aerodynamic calculation code based on a source singularities method, and droplet trajectories in the flow are determined using the method of Guffond (1985). The aerodynamic field in front of the air intake is shown to be significantly perturbed by the presence of the test section, and means of modifying the various parameters to remove the discrepancy between wind tunnel and flight data are proposed. R.R.

**A90-12619#****ICING TEST TECHNIQUES FOR AIR INTAKE SCREENS ON HELICOPTERS FUNCTIONING IN TEMPERATURES AROUND 0 C**

GUY BOMMELAER and PAUL CREISMEAS (Centre d'Essais des Propulseurs, Orsay, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1126-1132. Copyright

The icing behavior of helicopter air intake screens during flight at near 0 C temperature and high humidity has been investigated by CEP, the French Government Center for jet engine testing. Tests were performed to show correct functioning of the air intake under conditions in which there might be internal water streaming down behind the screens, and to demonstrate that the amount of ice eventually collected causes no damage to the engine. A model on the air intake of the AS332 helicopter equipped with the TM319 engine was satisfactorily tested, along with two types of air intakes of the Aerospatiale model AS365. The procedure can still be improved upon, in particular by including calculations on the power of the engine. C.E.

**A90-12620#****WATER INGESTION SIMULATION - TEST NEEDS**

S. N. B. MURTHY and C. M. EHRESMAN (Purdue University, West Lafayette, IN) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1133-1141. refs Copyright

One of the main problems in testing and certification of engines with respect to rain water ingestion is the determination of test environment and conditions that correspond on ground to those occurring in actual flight. Although some of the tests undertaken in flight may be useful, the most satisfactory means of establishing test conditions consist in engine and component performance estimation by analytical/computational procedures. Such procedures have to be evolved, however, based on tests in order to ensure the validity of physical models. Based on available test results, a model and a numerical prediction scheme (WINCOF-I) have been developed for the fan-compressor unit. Utilizing the predicted performance from that code and certain parameterized values for combustor performance, engine simulations have been carried out for a variety of ingestion conditions. It is concluded that in the near future only a combination of predictions and tests can provide adequate bases for evaluating an engine. Author

**A90-12781****COPING WITH BOMB THREATS TO CIVIL AVIATION**

I. M. BAR-NIR and R. L. COLE (Science Application International Corp., San Diego, CA) ICAO Bulletin (ISSN 0018-8778), vol. 44, June 1989, p. 11-15. Copyright

An FAA-approved explosive detection system is presented and compared with other detection systems. The system uses thermal neutrons to activate elements specific to explosives in order to detect the explosive during scanning. The principles of operating the thermal neutron analysis concept and the space, installation, and placement requirements of the system are presented. The thermal neutron analysis method is compared with manual searches, vapor detection, and gamma ray and neutron analysis. R.B.

**A90-12782****AVIATION SECURITY (AVSEC)**

M. A. ALEMAN (International Civil Aviation Organization, Technical Assistance Bureau, Bangkok, Thailand) ICAO Bulletin (ISSN 0018-8778), vol. 44, June 1989, p. 23-26. Copyright

The ICAO Asia/Pacific Regional Aviation Security (Avsec) Project is discussed. The project was conducted to enhance the aviation security capabilities of governments in the Asia/Pacific region. The program provided 24 developing countries in the region with assistance in the fields of aviation security expertise, training, and the procurement of security equipment. The methodology and results of the project are described, noting the importance of follow-up commitment to the project. R.B.

### 03 AIR TRANSPORTATION AND SAFETY

**N90-10013#** National Transportation Safety Board, Washington, DC.

**AIRCRAFT ACCIDENT REPORT: ALOHA AIRLINES, FLIGHT 243, BOEING 737-200, N73711, NEAR MAUI, HAWAII, APRIL 28, 1988**

28 Apr. 1988 263 p

(PB89-910404; NTSB/AAR-89/03) Avail: NTIS HC A12/MF A01 CSCL 01/3

On April 28, 1988, a Boeing 737-200, N73711, operated by Aloha Airlines Inc., experienced an explosive decompression and structural failure at 24,000 feet, while en route from Hilo, to Honolulu, Hawaii. Approximately 18 feet of the cabin skin and structure aft of the cabin entrance door and above the passenger floorline separated from the airplane during flight. There were 89 passengers and 6 crewmembers on board. One flight attendant was swept overboard during the decompression and is presumed to have been fatally injured; 7 passengers and 1 flight attendant received serious injuries. The flightcrew performed an emergency descent and landing at Kahului Airport on the Island of Maui. The safety issues raised in this report include: the quality of air carrier maintenance programs and the FAS surveillance of those programs, the engineering airworthiness of the B-737 with particular emphasis on multiple site fatigue cracking of the fuselage lap joints, the human factors aspects of air carrier maintenance and inspection for the continuing airworthiness of transport category airplanes, to include repair procedures and the training, certification and qualification of mechanics and inspectors. Author

**N90-10014\*#** Boeing Commercial Airplane Co., Seattle, WA.

**CLASSIFICATION AND REDUCTION OF PILOT ERROR**

Report, Jan. 1988 - Feb. 1989

W. H. ROGERS, A. L. LOGAN, and G. D. BOLEY Sep. 1989 173 p

(Contract NAS1-18027)

(NASA-CR-181867; NAS 1.26:181867; DOT/FAA/DS-89/24)

Avail: NTIS HC A08/MF A01 CSCL 01/3

Human error is a primary or contributing factor in about two-thirds of commercial aviation accidents worldwide. With the ultimate goal of reducing pilot error accidents, this contract effort is aimed at understanding the factors underlying error events and reducing the probability of certain types of errors by modifying underlying factors such as flight deck design and procedures. A review of the literature relevant to error classification was conducted. Classification includes categorizing types of errors, the information processing mechanisms and factors underlying them, and identifying factor-mechanism-error relationships. The classification scheme developed by Jens Rasmussen was adopted because it provided a comprehensive yet basic error classification shell or structure that could easily accommodate addition of details on domain-specific factors. For these purposes, factors specific to the aviation environment were incorporated. Hypotheses concerning the relationship of a small number of underlying factors, information processing mechanisms, and error types types identified in the classification scheme were formulated. ASRS data were reviewed and a simulation experiment was performed to evaluate and quantify the hypotheses. Author

**N90-10841\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**DESIGN OF A FINAL APPROACH SPACING TOOL FOR TRACON AIR TRAFFIC CONTROL**

THOMAS J. DAVIS, HEINZ ERZBERGER, and HUGH BERGERON Sep. 1989 27 p Prepared in cooperation with NASA. Langley Research Center, Hampton, VA

(NASA-TM-102229; A-89235; NAS 1.15:102229) Avail: NTIS HC A03/MF A01 CSCL 01/3

This paper describes an automation tool that assists air traffic controllers in the Terminal Radar Approach Control (TRACON) Facilities in providing safe and efficient sequencing and spacing of arrival traffic. The automation tool, referred to as the Final Approach Spacing Tool (FAST), allows the controller to interactively choose various levels of automation and advisory information ranging from predicted time errors to speed and heading advisories

for controlling time error. FAST also uses a timeline to display current scheduling and sequencing information for all aircraft in the TRACON airspace. FAST combines accurate predictive algorithms and state-of-the-art mouse and graphical interface technology to present advisory information to the controller. Furthermore, FAST exchanges various types of traffic information and communicates with automation tools being developed for the Air Route Traffic Control Center. Thus it is part of an integrated traffic management system for arrival traffic at major terminal areas. Author

**N90-10842#** National Oceanic and Atmospheric Administration, Boulder, CO. Wave Propagation Lab.

**REMOTE SENSING TECHNIQUES OF THE WAVE PROPAGATION LABORATORY FOR THE MEASUREMENT OF SUPERCOOLED LIQUID WATER: APPLICATIONS TO AIRCRAFT ICING**

E. R. WESTWATER and R. A. KROPFLI May 1989 35 p

(PB89-208102; NOAA-TM-ERL-WPL-163) Avail: NTIS HC A03/MF A01 CSCL 01/3

The technical memorandum reviews the processes causing aircraft icing, describes promising new remote sensing instruments and methodologies, and suggests how these can be applied to help solve the aircraft icing problem. Author

**N90-10843#** Questek, Inc., Centerport, NY.

**SEE AND AVOID/COCKPIT VISIBILITY**

WALTON GRAHAM Oct. 1989 25 p

(DOT/FAA/CT-TN89/18) Avail: NTIS HC A03/MF A01

This study was conducted in response to the Federal Aviation Administration's (FAA) Office of Aviation Safety and the recommendations of the Interagency Near Midair Collision (NMAC) Working Group, dated July 21, 1986, which suggested a review of see and avoid effectiveness, conspicuity enhancement, and their relationship to cockpit visibility. This report summarizes the salient facts in these areas, based on a review of the literature, and assesses the potential for significant reduction of collision risk. The study was conducted by Walton Graham, Questek, Incorporated, who was previously involved in numerous FAA see and avoid, pilot warning instrument/collision risk studies and analyses of the near midair collision data. Author

**N90-10844#** Oak Ridge National Lab., TN. Computing and Telecommunications Div.

**A PRELIMINARY SENSITIVITY ANALYSIS OF THE GENERALIZED ESCAPE SYSTEM SIMULATION (GESS) COMPUTER PROGRAM**

JONAS T. HOLDEMAN, GUNAR E. LIEPINS, BRIAN D. MURPHY, SANG Y. OHR, THOMAS J. SWORSKI, and GORDON E. WARNER Jun. 1989 17 p

(Contract DE-AC05-84OR-21400)

(DE89-016891; ORNL/CSD/TM-250) Avail: NTIS HC A03/MF A01

The Generalized Escape System Simulation (GESS) program is a computerized mathematical model for dynamically simulating the performance of existing or developmental aircraft ejection seat systems. The program generates trajectory predictions with 6 degrees of freedom for the aircraft, seat/occupant, occupant alone, and seat alone systems by calculating the forces and torques imposed on these elements by seat catapults, rails, rockets, stabilization and recovery systems included in most escape system configurations. User options are provided to simulate the performance of all conventional escape system designs under most environmental conditions and aircraft attitudes or trajectories. The concept of sensitivity analysis is discussed, as is the usefulness of GESS for retrospective studies, whereby one attempts to determine the aircraft configuration at ejection from the ejection outcome. A very limited and preliminary sensitivity analysis was done with GESS to study the way the performance of the ejection system changes with certain user-specified options or parameters. A more complete analysis would study correlations, where simultaneous correlated variations of several parameters might affect performance to an extent not predictable from the individual

sensitivities. Uncertainty analysis is discussed. Even with this limited analysis, a difficulty with some simulations involving a rolling aircraft was discovered; the code produces inconsistent trajectories. One explanation is that the integration routine is not able to deal with the stiff differential equations involved. Another possible explanation is that the coding of the coordinate transformations is faulty when large angles are involved. DOE

**N90-10845#** General Accounting Office, Washington, DC. National Security and International Affairs Div.

**TEST AND EVALUATION: REDUCING RISKS TO MILITARY AIRCRAFT FROM BIRD COLLISIONS. REPORT TO THE CHAIRMAN, LEGISLATION, AND NATIONAL SECURITY SUBCOMMITTEE, COMMITTEE ON GOVERNMENT OPERATIONS, HOUSE OF REPRESENTATIVES**

13 Jul. 1989 29 p  
(AD-A210670; GAO/NSIAD-89-127) Avail: NTIS HC A03/MF A01 CSCL 01/3

This report responds to a request concerning military aircraft testing against bird collisions and development of nonflammable hydraulic fluid. We specifically reviewed: (1) the extent of bird collision damage to military aircraft, (2) the specifications for testing engines against bird collisions, (3) the relationship between engine contractors and the government during tests to identify risks from bird collisions, and (4) the development and use of nonflammable hydraulic fluid to reduce risks from fires. We also reviewed some nontesting measures to reduce the risk to military aircraft, such as bird avoidance efforts and the redesign of aircraft transparencies to withstand bird collisions. GRA

## 04

## AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

**A90-10239****EUROFIX**

DURK VAN WILLIGAN (Delft, Technische Universiteit, Netherlands) Journal of Navigation (ISSN 0373-4633), vol. 42, Sept. 1989, p. 375-381. refs  
Copyright

A differential integrated/hybridized positioning system for Western Europe, known as Eurofix, is proposed. The Eurofix concept integrates the Loran-C data link, the accuracy of Navstar/GPS, and the repeatability of Loran-C. The system would install reference Navstar/GPS receivers at all Loran-C transmitter sites, using the Loran-C transmitters to serve the full European area with correction data. The possible navigation modes in which Eurofix could operate are outlined and the technical and cost requirements of installing the system are discussed. R.B.

**A90-10240**

**EVALUATING THE FEASIBILITY OF A RADAR SEPARATION MINIMUM FOR A LONG-RANGE SSR**

SAKAE NAGAOKA, OSAMU AMAI, and YASUO WATANABE (Ministry of Transport, Electronic Navigation Research Institute, Tokyo, Japan) Journal of Navigation (ISSN 0373-4633), vol. 42, Sept. 1989, p. 403-416. refs  
Copyright

This paper deals with an analytical method for establishing a separation minimum for air traffic control using a monopulse SSR (Secondary Surveillance Radar), namely the Long Range SSR (LSSR), of which coverage is extended to 250 nm. The azimuth estimation accuracy of the monopulse SSR was significantly improved compared with that of conventional SSR. As an index of a collision risk due to azimuth errors of the LSSR, the close approach probability (CAP) associated with the probability of overlap of aircraft in azimuth is used for evaluating the safety of

the surveillance system. The CAPs for both the LSSR and the conventional SSR are estimated by modeling and comparing distributions of azimuth errors. The CAP for the LSSR is significantly smaller than that for the conventional one under 5 nm separation minimum. Author

**A90-10462**

**TERMINAL DOPPLER WEATHER RADAR SYSTEM - WIND SHEAR DETECTION WILL WARN PILOTS OF DANGER**

J. MICHAEL CONNELLY (Raytheon Co., Lexington, MA) ICAO Bulletin (ISSN 0018-8778), vol. 44, April 1989, p. 14-17. Copyright

The Terminal Doppler Weather Radar (TDWR) system, which is designed to detect hazardous wind shear, microbursts, gust fronts, and precipitation intensity, and to provide early warning to air traffic controllers and pilots, is discussed. The hazardous nature of wind shear and the background to the TDWR system are briefly reviewed, and the meteorological data which are most needed for the TDWR to function optimally are pointed out. The automation and future prospects of the TDWR system are addressed. C.D.

**A90-10502#****REFLEXIVE NAVIGATION FOR AUTONOMOUS AIRCRAFT**

STEPHEN D. TYNOR (Georgia Institute of Technology, Atlanta) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 218-224. refs (AIAA PAPER 89-2991) Copyright

REFLEX applies recent research in animal behavior to autonomous aircraft navigation. In REFLEX, complex navigational behaviors are built from very simple competing sub-behaviors, or schemas. For example, by defining two simple behaviors: move-in-direction, which instructs the vehicle to move in a particular direction, and avoid-obstacle, which motivates the vehicle to move away from an object, the vehicle can exhibit remarkably 'intelligent' behavior of moving in a particular direction until perceiving an obstacle then maneuvering around the obstacle and continuing on its way. What makes this method of navigation so powerful is that it requires no high level reasoning or planning in the traditional use of the term. The method described has potential application for both autonomous navigation as well as intelligent autopilots. Author

**A90-10571#****TRENDS IN TELEMETRY FRONT END ARCHITECTURE**

ERWIN H. STRAEHLEY (Straehley Associates, Santa Barbara, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 776-781. refs (AIAA PAPER 89-3085) Copyright

Trends in telemetry are discussed within the context of the flight testing of aerospace vehicles such as aircraft and missiles. Particular attention is given to digital systems employing pulse modulation. A telemetry system model consisting of data input, vehicle processor, transmission, terminal processor, post processor, and user interface sections is used to define the terminology. The factors driving the front end design are discussed. K.K.

**A90-10572#****TRENDS IN REAL-TIME FLIGHT SYSTEMS**

LARRY SHELLEY (Computer Sciences Realtime Data Systems Center, Lompoc, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 782-784. (AIAA PAPER 89-3086) Copyright

The influence of technological progress on real-time flight test systems is discussed. Consideration is given to real-time processor architectures, expansion and flexibility, communications and networking, data presentation, AI, data archiving and post-flight processing, and system development/documentation methodologies. It is argued that a combination of advancing

## 04 AIRCRAFT COMMUNICATIONS AND NAVIGATION

technology and user requirements will push the future flight test system into becoming a more intelligent extension of the user's working environment. K.K.

**A90-10841**

### **RADAR SYSTEMS OF AIRCRAFT [RADIOLOKATSIONNYE SISTEMY VOZDUSHNYKH SUDOV]**

PAVEL S. DAVYDOV, ANATOLII I. KOZLOV, VIKTOR S. UVAROV, E. A. LUTIN, B. G. GRUZDEV et al. Moscow, Izdatel'stvo Transport, 1988, 360 p. In Russian. refs  
Copyright

The principles of the general structural and functional design of the radar systems of aircraft, including navigation radars, Doppler velocimeters, and radar responders, are reviewed. The discussion covers the fundamentals of the probabilistic processing of radar signals; antennas of airborne radars; transmitting and receiving devices of aircraft radars; and digital devices for the reception and processing of radar data. Attention is also given to air traffic control radars, radar maintenance and repair, and prospects for the future development of radar systems. V.L.

**A90-11696**

### **AN INTELLIGENT SYSTEM FOR AUTONOMOUS NAVIGATION OF AIRBORNE VEHICLES**

WILLIAM L. CAMERON, HOWARD FAIN (Boeing Aerospace, Seattle, WA), and JAMES C. BEZDEK (Boeing Electronics, Seattle, WA) IN: Sensor fusion: Spatial reasoning and scene interpretation; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 451-469. refs  
Copyright

Autonomous navigation of airborne platforms requires the integration of diverse sources of sensor data and contextual information. This paper describes a system that utilizes polarimetric radar cross-section and range data to generate position estimates based on four kinds of information: area segmentation, ground contours, landmarks, and road networks. Ground truth in the form of terrain feature maps is correlated with each type of data stream. Finally, an arbitrator integrates these inputs with contextual knowledge about the preplanned flight path to resolve conflicts and arrive at a final estimate of current position. Author

**A90-11813**

### **LASER COMMUNICATION SYSTEM DESIGN**

W. L. CASEY, G. R. DOUGHTY, J. G. HOUSTON, R. K. MARSTON, L. J. O'PELLA (Rockwell International Corp., Richardson, TX) et al. IN: High data rate atmospheric and space communications; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 28-35.  
Copyright

The Air Force is interested in laser communication systems for a variety of air-to-air applications. The applications with the greatest near-term potential involve the transfer of data between large aircraft operating in relatively benign dynamic environments normally present at altitudes of about 30,000 feet. Systems performing these strategic data exchange (SDE) functions must operate at ranges of 100 to 200 nautical miles at data rates of 2 to 3 megabits per second and probability of bit error rates not exceeding 10 to the -6th. The major communication channel elements of a design for a lasercom system performing SDE roles are discussed. The design is established by comparing the advantages of the different approaches and the final design selection is based on the transmitter characteristics required for each system. The characteristics include physical properties, development risk, cost, and the flexibility for meeting more stringent system performance specifications without requiring major design. C.E.

**A90-12189**

### **RESEARCH ON TRANSMISSION QUALITY OF TELEMETRY SYSTEM IN FLIGHT TEST**

PEI-FENG HUO (China Flight Test Research Centre, People's

Republic of China) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 141-151.  
Copyright

In flight test of aircraft, the transmission quality of telemetry system can be represented with the transient loss of telemetry signal, signal distortion and noise. In this paper, the transmission quality of telemetry system in meter-band and S-band has been described from two sides of theoretical analyses and flight test. Through analyses of flight testing results it is shown that the airborne transmitting antenna pattern, polarization of receiving antenna on the ground, path of radio wave propagation and interference, etc., are the main reasons for the signal loss. The transient lost signals are much more accidental in flight test for a telemetry system if the configuration of the system is perfect and correct in application. It is not serious for the measured results of parameters and telemetry data processing. This paper offers some technical measures for improving the telemetry transmission quality. The conclusion points out that the transmission quality of telemetry in flight test is reliable. Author

**A90-12191**

### **DECOMMUTATION TECHNIQUES AND THEIR INTEGRATION INTO POST FLIGHT ANALYSIS SYSTEM**

G. VITALONE (Aeritalia S.p.A., Turin, Italy) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 245-253.  
Copyright

The paper describes the ground-based reproduction of Mil Bus 1553 B traffic at Aeritalia in connection with acquisition through the high-density data recorder. It is demonstrated that the acquisition, decommutation, and processing of the data coming from the Mil Bus can be simply performed by means of standard hardware products and dedicated, uncomplicated software. A general description of the architecture of both the hardware and the software environments is presented. B.J.

**A90-12192**

### **SYSTEM IDENTIFICATION - MULTIBUS ACQUISITION AND SIMULATION EQUIPMENT**

CHRISTIAN SASSO (Avions Marcel Dassault-Breguet Aviation, Istres, France) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 265-277. In English and French.  
Copyright

Equipment whose architecture is based on a commercial minicomputer has been developed for the acquisition and simulation of various types of buses as well as analog data encountered on Avions Marcel Dassault-Breguet Aviation aircraft. The equipment, called OSIRIS (high-speed data capture computer for system identification) can be installed in a laboratory or in a service vehicle. Hardware and software descriptions of OSIRIS are given. B.J.

**A90-12194**

### **ACQUISITION AND RECORDING OF AMX A/C AERITALIA EXPERIENCE AND PRESENT TRENDS**

S. CATTUNAR (Aeritalia S.p.A., Turin, Italy) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 291-302.  
Copyright

The AMX prototype A03 is the first Aeritalia aircraft that makes use of Bus 1553 B as an active link for all avionic, navigation, and armament equipment. The AMX flight test instrumentation is described; emphasis is placed on two acquisition techniques adopted for the 1553 Bus: through a PCM acquisition system and directly on a magnetic tape recorder. Both techniques were shown to yield satisfactory results. B.J.

**A90-12250**

**NAVSTAR-GPS: AN EVOLUTION OR A REVOLUTION, ECOLE SUPERIEURE D'ELECTRICITE, GIF-SUR-YVETTE, FRANCE, FEB. 11, 1987, WORKSHOP [NAVSTAR-GPS: UNE EVOLUTION OU UNE REVOLUTION, ECOLE SUPERIEURE D'ELECTRICITE, GIF-SUR-YVETTE, FRANCE, FEB. 11, 1987, JOURNEE D'ETUDES]**

Workshop sponsored by CNES. Paris, Societe des Electriciens et des Electroniciens, 1987, 176 p. In French. No individual items are abstracted in this volume.

Papers are presented on such topics as GPS coverage, inertial/GPS integration, a GPS channel adapted to integration with inertial navigation, and GPS-loran integration. Attention is also given to precise position determination with GPS, time-frequency measurements in the framework of GPS, differential Navstar, and the role of Navstar in civil aviation. B.J.

**A90-12752#**

**A PRECISE FLIGHT REFERENCE SYSTEM FOR EVALUATING AIRBORNE NAVIGATION AIDS**

D. J. DIFILIPPO (Defence Research Establishment Ottawa, Canada) and B. W. LEACH (National Aeronautical Establishment, Ottawa, Canada) (Canadian Symposium on Navigation, 7th, Montreal, Canada, May 1988) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 35, Sept. 1989, p. 138-146. refs

DREO, supported by NAE, has developed and implemented a flight reference system (FRS) that provides precise continuous estimates of aircraft horizontal position, horizontal velocity, attitude, and heading. Such information is required to properly evaluate various types of airborne navigation and guidance systems. The FRS design is based on a Kalman filter that optimally integrates the outputs of an LTN-91 inertial navigation system with microwave ranging information from a Trisponder system. With range measurements from at least two transponders having a reasonably good geometry, the FRS is able to estimate aircraft horizontal components of position and velocity to an accuracy of about 10 m rms and 0.1 m/s rms, respectively, aircraft roll and pitch to 0.3 arcmin rms, and aircraft heading to 1 arcmin rms. At the same time, the Kalman filter uses the range measurements to estimate accurately the LTN-91 errors, so that, during short intervals of poor transponder geometry or range outages, the FRS can still use a well-calibrated LTN-91 to provide good-quality reference data. This paper describes the various components of the FRS, including the sensors and the off-line processor. Simulation data are presented to show the achievable FRS accuracies. Results from processing raw flight data recorded on the NAE Convair 580 are also provided as an indication of FRS performance. Author

**N90-10016#** Office of Technology Assessment, Washington, DC.

**SAFER SKIES WITH TCAS: TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM Special Report**

Feb. 1989 63 p

(PB89-169221; OTA-SET-431; LC-89-600725) Avail: NTIS HC A04/MF A01; SOD HC \$2.50 as 052-003-01149-2 CSCL 17/7

Because midair collisions between aircraft are nearly always catastrophic, the aviation community has been working for many years to develop technologies to help prevent such tragedies. These efforts have culminated in a cooperative government-industry program to develop, evaluate, and implement a traffic alert and collision avoidance system (TCAS 2) for commercial aviation. The 100th Congress passed legislation requiring that most commercial passenger aircraft be equipped with TCAS 2 by December 1991, or they would not be permitted to fly in U.S. airspace. However, during the second half of 1988, questions arose about the safety implications of the certification and implementation schedule for TCAS 2. The Office of Technology Assessment (OTA) was asked to assess these implications. This report contains the results of OTA's assessment. K.C.D.

**N90-10017#** Mitre Corp., McLean, VA.

**NATIONAL AIRSPACE SYSTEM APPROACH AND DEPARTURE SEQUENCING OPERATIONAL CONCEPT Final Report, Jun. 1989**

JOSEPH P. IADELUCA Mar. 1989 44 p

(Contract DTFA01-89-C-00001)

(NAS-SR-1322; DOT/FAA/DS-89/25) Avail: NTIS HC A03/MF A01

This concept of operations is one of many high level documents that will, in total, describe the operations of the National Airspace System (NAS) when the NAS Plan has been implemented. These documents as a set will assist in linking the requirements specified in NAS System Requirements Specification (NASSRS) with the NAS design. One of the functions of the NAS is to support approach and departure sequencing at specific airports. The objective of this document is to describe the relationship among subsystems, facilities, information, and operators/users involved in the approach and departure sequencing function. This document is intended as a tool for system designers, analysts, and test planners. The document contains several types of block diagrams illustrating system connectivity, and operational flow. These diagrams in conjunction with the text are intended to provide perspective and insight into the NAS approach and departure sequencing function. Author

**N90-10018#** Federal Aviation Administration, Atlantic City, NJ. **ILS/MLS COMPARISON TESTS AT MIAMI/TAMIAMI, FLORIDA AIRPORT**

JOHN TOWNSEND Jul. 1989 20 p

(Contract FAA-T0604-L)

(ACD-330; DOT/FAA/CT-TN89/39) Avail: NTIS HC A03/MF A01

A series of flight tests were performed by the Federal Aviation Administration (FAA) Technical Center at the Miami/Tamiami, Florida Airport, to compare the course quality of an instrumented landing system (ILS) with a collocated Microwave Landing System (MLS). The Technical Center's test bed MLS was transported to and collocated with the commissioned category 1 ILS on runway 9R at Tamiami. The flight data that was collected indicate that the MLS has less scalloping than the ILS and the MLS azimuth is unaffected by overflight interference. Author

**N90-10019#** Federal Aviation Administration, Atlantic City, NJ. **ILS (INSTRUMENT LANDING SYSTEM) MATHEMATICAL MODELING STUDY ON THE EFFECTS OF PROPOSED HANGAR CONSTRUCTION WEST OF RUNWAY 18R ON LOCALIZER PERFORMANCE AT DALLAS-FORT WORTH INTERNATIONAL AIRPORT Technical Note, period ending Mar. 1989**

JAMES D. RAMBONE and JOHN E. WALLS Jun. 1989 21 p (AD-A210631; DOT/FAA/CT-TN89/29) Avail: NTIS HC A03/MF A01 CSCL 01/5

This Technical Note describes the instrument landing system (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Southwest Region. Computed data are presented showing the effects of several proposed hangar configurations on the performance of the ILS localizer for runway 18R at the Dallas-Fort Worth International Airport. The Southwest Region is concerned that reflections from the proposed hangars may degrade the localizer course beyond category II tolerances. Modeled course structure results indicate that category II localizer performance should be obtained with the existing 14/6 Type IB antenna for the proposed hangar configurations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels. GRA

**N90-10020#** Federal Aviation Administration, Atlantic City, NJ. **THE ADDITION OF BENDIX MLS (MICROWAVE LANDING SYSTEM) ANTENNA PATTERNS TO MLS MATHEMATICAL MODEL Technical Note, Jan. - Feb. 1989**

JESSE D. JONES May 1989 120 p

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(AD-A210633; DOT/FAA/CT-TN89/26) Avail: NTIS HC A06/MF A01 CSCL 17/7

Bendix Microwave Landing System (MLS) test bed antenna patterns were added to the MLS mathematical model. This report documents the method of installation, the required alterations of existing code to support the new patterns, and the results of testing of the new patterns with standard test scenario two. The tests yielded acceptable results. GRA

**N90-10021\*#** Theory and Applications Unlimited Corp., Los Gatos, CA.

### **GUIDANCE SIMULATION AND TEST SUPPORT FOR DIFFERENTIAL GPS FLIGHT EXPERIMENT**

G. J. GEIER, P. V. W. LOOMIS, and A. CABAK Oct. 1987 47 p  
(Contract NAS2-12378)  
(NASA-CR-177471; NAS 1.26:177471) Avail: NTIS HC A03/MF A01 CSCL 17/7

Three separate tasks which supported the test preparation, test operations, and post test analysis of the NASA Ames flight test evaluation of the differential Global Positioning System (GPS) are presented. Task 1 consisted of a navigation filter design, coding, and testing to optimally make use of GPS in a differential mode. The filter can be configured to accept inputs from external sensors such as an accelerometer and a barometric or radar altimeter. The filter runs in real time onboard a NASA helicopter. It processes raw pseudo and delta range measurements from a single channel sequential GPS receiver. The Kalman filter software interfaces are described in detail, followed by a description of the filter algorithm, including the basic propagation and measurement update equations. The performance during flight tests is reviewed and discussed. Task 2 describes a refinement performed on the lateral and vertical steering algorithms developed on a previous contract. The refinements include modification of the internal logic to allow more diverse inflight initialization procedures, further data smoothing and compensation for system induced time delays. Task 3 describes the TAU Corp participation in the analysis of the real time Kalman navigation filter. The performance was compared to that of the Z-set filter in flight and to the laser tracker position data during post test analysis. This analysis allowed a more optimum selection of the parameters of the filter. Author

**N90-10847#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

### **KALMAN FILTER INTEGRATION OF MODERN GUIDANCE AND NAVIGATION SYSTEMS**

Jun. 1989 181 p In ENGLISH and FRENCH Lecture series held in Delft, Netherlands, 26-27 Jun. 1989, in Neubiberg, Fed. Republic of Germany, 29-30 Jun. 1989, and in London, England, 3-4 Jul. 1989  
(AGARD-LS-166; ISBN-92-835-0514-X) Copyright Avail: NTIS HC A09/MF A01

The integration of modern guidance and navigation systems is usually performed with a suboptimal implementation of the Kalman filter. The most difficult problem is how to develop that suboptimal implementation when considering system modeling, algorithm design, and real hardware nonlinearities. This lecture series brings together a group of speakers with outstanding practical experience in the design of integrated systems, providing the audience with the principles, insights, and mechanisms of real, current-day system synthesis approaches, and giving the overall background necessary for synthesizing future practical guidance and navigation systems. Two of the lectures deal with the synthesis of solutions to tracking problems. The remainder of the lectures deal with the integrations of avionics systems.

**N90-10855#** Computer Resource Management, Inc., Vienna, VA.

### **GROUND AND OBSTACLE AVOIDANCE (GOA) CONCEPT OF OPERATIONS**

WILLIAM TRENT, RODNEY KUHN, and THOMAS PICKERELL

Jun. 1989 39 p

(Contract DTFA01-88-Y-10173)

(DOT/FAA/DS-89/08) Avail: NTIS HC A03/MF A01

A requirement for the National Airspace System (NAS) is to provide for detecting the need for and assisting in ground and obstacle avoidance activities, as identified in the NAS System Requirement Specification, NAS-SR-1000. A concept is presented of operations for ground and obstacle avoidance. Ground and obstacle avoidance assistance capabilities are described and the relationships are shown between subsystems, facilities, information, and operators/users. A common perspective is provided for personnel involved in ground and obstacle avoidance activities, assist in determining whether the ground and obstacle avoidance activities meet formal requirements, and support coordination among the organizations involved. Author

### **N90-10856#** Federal Aviation Administration, Atlantic City, NJ. **HELICOPTER VISUAL SEGMENT APPROACH LIGHTING SYSTEM (HALS) Test Report**

BARRY R. BILLMANN and SCOTT SHOLLENBERGER Jun. 1989 318 p  
(Contract FAA-T0701-U)  
(ACD-330; DOT/FAA/CT-TN89/21) Avail: NTIS HC A14/MF A02

A test designed to obtain pilot performance subjective pilot data on the Helicopter Visual Segment Approach Lighting System (HALS) is reported. Results identify the performance measures which correlate with the pilot's ability to visually acquire a HALS equipped heliport. Conclusions state that HALS can support existing minima to heliports. Pilots reported unacceptable Cooper-Harper ratings for rate of closure and workload without HALS. Author

## 05

## **AIRCRAFT DESIGN, TESTING AND PERFORMANCE**

Includes aircraft simulation technology.

**A90-10226#**

### **A MULTIFUNCTIONAL SYSTEM OF HELICOPTER DYNAMICS SIMULATIONS [WIELOFUNKCYJNY SYSTEM BADAN SYMULACYJNYCH DYNAMIKI SMIGLOWCOW]**

KAZIMIERZ SZUMANSKI (Instytut Lotnictwa, Warsaw, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 112-113, 1988, p. 3-23. In Polish. refs

The idea of constructing a multifunctional system for the dynamical testing of helicopters presented here is based on the use, as a central module, of a model of the rotor (1) or the helicopter (2) and a set of models transforming the results of the fundamental solution to a form used in design practice. Such a system belongs to a group of measuring systems, because it presents (in transforming systems) the measurement techniques or the form in which the measurement results are obtained. Author

**A90-10227#**

### **SOME UNCONVENTIONAL CASES OF THE DYNAMICAL TESTING OF HELICOPTERS [NIEKONWENCJONALNE PRZYPADKI BADAN DYNAMIKI SMIGLOWCOW]**

KAZIMIERZ SZUMANSKI (Instytut Lotnictwa, Warsaw, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 112-113, 1988, p. 24-60. In Polish. refs

The paper deals with some nonclassical stressing cases for the helicopter structure not mentioned in the helicopter airworthiness requirements. Such cases are often decisive for the dimensioning of the structure, as a consequence of unconventional design solutions. The difficulties of structural analysis, which result in such cases from the complexity of the phenomena occurring in the structure, necessitate rough approximations and result in

experimental investigations being preferred to theoretical studies. In the cases mentioned here, studies are performed by modeling the helicopter structure and simulating the typical phenomena involved.

Author

#### A90-10230#

##### WIND TUNNEL TESTS OF MODELS OF HELICOPTER ROTORS [BADANIA MODELI WIRNIKOW NOSNYCH SMIGLOWCOW W TUNELU AERODYNAMICZNYM]

JANUSZ NARKIEWICZ (Warszawa, Politechnika; Instytut Lotnictwa, Warsaw, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 112-113, 1988, p. 108-130. In Polish. refs

Some problems of model tests of helicopter rotors are discussed on the basis of the results of a series of wind tunnel tests of a helicopter rotor with elastic rigidly fixed blades, which were performed at the Institute of Aeronautics, Warsaw. The discussion includes criteria of aeroelastic similarity between the real rotor and the model, the structure of the helicopter rotor head and blades, and the equipment for recording and processing the measurement results and preliminary or complementary tests. Some examples of measurement results are presented along with a method for using them to estimate the properties of the rotor.

Author

#### A90-10349#

##### THE STUDY OF THE THEORETICAL CALCULATION METHOD FOR POWER STALL DYNAMIC CHARACTERISTICS OF MULTIPLE-ENGINE PROPELLER AIRPLANE

MAOFU LING (Shanghai Aircraft Design and Research Institute, People's Republic of China) and KAIFENG HE (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, Sept. 1989, p. 370-376. In Chinese, with abstract in English. refs

The equations for analyzing the power stall dynamic characteristics of the multiple-engine propeller aircraft are derived and used to study the power stall dynamic characteristics of the aircraft. The method can also be used to study the fully digital real-time imitation of power stall characteristics of the aircraft and can be used in a stall/spin flight simulator.

C.D.

#### A90-11006#

##### OPTIMIZATION OF HELICOPTER TAKEOFF AND LANDING

T. CERBE and G. REICHERT (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings, Volume 1, p. 154-164) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 925-931. Previously cited in issue 03, p. 264, Accession no. A89-13521. refs

(Contract DFG-SFB-212)

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#### A90-11007#

##### WING-SECTION EFFECTS ON THE FLIGHT PERFORMANCE OF A REMOTELY PILOTED VEHICLE

J. L. STOLLERY and D. J. DYER (Cranfield Institute of Technology, England) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings, Volume 2, p. 1392-1401) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 932-938. Research supported by the Ministry of Defence. Previously cited in issue 03, p. 266, Accession no. A89-13641. refs

Copyright

#### A90-11009#

##### DESIGN OF AN ADVANCED PNEUMATIC DEICER FOR THE COMPOSITE ROTOR BLADE

NORBERT A. WEISEND, JR. (BF Goodrich Co., Uniontown, OH) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 947-950. Previously cited in issue 07, p. 945, Accession no. A88-22015. refs

Copyright

#### A90-11875#

##### A NEW HYBRID AIRSHIP ('HELISHIP') FOR COMMUTER TRANSPORT

SHIGENORI ANDO (Nagoya University, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 32, Aug. 1989, p. 79-93. Previously cited in issue 24, p. 3773, Accession no. A89-53641. refs

#### A90-12253

##### MODERN DYNAMIC COMPONENTS FOR HELICOPTERS [MODERNE DYNAMISCHE KOMPONENTEN FUER HUBSCHRAUBER]

VOLKER VON TEIN (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) Jahrbuch der Wehrtechnik (ISSN 0075-2428), no. 18, 1988, 13 p. In German. (ISBB-UD-556-89-PUB) Copyright

The state of the art in the dynamic components of helicopters is reviewed, emphasizing the situation in the FRG. Rotor technology is addressed in detail, reviewing the evolution of helicopter rotors, discussing the jointless rotor and the bearingless main rotor, and presenting diagrams. Engines and vibration isolation systems are briefly considered.

C.D.

#### A90-12258#

##### ROTOR CONCEPTS FOR THE EUROPEAN FUTURE ADVANCED ROTORCRAFT (EUROFAR)

ROLAND WENNEKERS (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) Royal Aeronautical Society, European Future Advanced Rotorcraft Symposium, London, England, Apr. 11, 1989, Paper. 16 p. (ISBB-UD-0551-89-PUB)

The development of the European Future Advanced Rotorcraft (Eurofar) is discussed, focusing on prop rotor development. The basic requirements for the prop rotor layout are outlined. The aerodynamic design and aeroelastic rotor stability of the tilt rotor are examined. Various design concepts are described. It is recommended that the concept for design refinement should be the four-bladed gimbal rotor.

R.B.

#### A90-12612#

##### STUDY OF ADVANCED TECHNOLOGY IMPACT ON CYCLE CHARACTERISTICS AND AIRCRAFT SIZING (USING MULTIVARIABLE OPTIMIZATION TECHNIQUES)

E. J. KOWALSKI and E. TJONNELAND (Boeing Advanced Systems, Seattle, WA) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings, Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1053-1063. Copyright

The Air Force Wright Aeronautical Laboratories predict that, by the turn of the century, advanced turbine component technologies will be applicable to a broad range of propulsive systems. Studies described include the use of a multivariable optimization technique applied to show how technology improvements can be utilized to define engine cycles matched to aircraft/mission requirements and to show resulting payoff in aircraft size reduction. A multitude of fundamental figures-of-merit must be investigated that account for the interactive effects between aircraft/engine/mission independent design variables. Multivariable optimization techniques must be considered to efficiently accomplish such studies. Engines with technology levels from 1980 to 2002, powering a Mach 2.0 tactical fighter on a 800-nautical-mile radius mission are compared. A 31 percent reduction in aircraft takeoff gross weight resulted for the high technology engine.

C.E.

#### A90-12613#

##### ANALYTICAL METHODS FOR SUBSONIC PROPULSION SYSTEM INTEGRATION

J. L. COLEHOUR, B. W. FARQUHAR, and T. A. REYHNER (Boeing Commercial Airplanes, Seattle, WA) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989,



## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1064-1069. refs  
Copyright

Design of propulsion installations for subsonic transport aircraft is, at best, a difficult task because of the complex nature of the geometry and flows involved. This paper presents a method by which analytical predictions can be made for most features of the flow about propulsion installations so that initial design decisions can be made without resorting to tests. The method consists of a very general transonic potential flow analysis and an engine jet plume simulation used in an iterative process. Correlations of the analysis with wind tunnel data show that agreement is excellent. It is concluded that flow analysis can be used to study many important features of subsonic transport propulsion installations and that it exhibits sufficient accuracy to be used in making preliminary design decisions in the configuration development process. Author

**A90-12768**

### **SYSTEM IDENTIFICATION STRATEGIES FOR HELICOPTER ROTOR MODELS INCORPORATING INDUCED FLOW**

R. BRADLEY, C. G. BLACK, and D. J. MURRAY-SMITH (Glasgow, University, Scotland) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 281-293. Research supported by the Ministry of Defence of England. refs

Copyright

A technique based primarily on frequency-domain output-error methods is presented for the identification of rotor models. Strategies involving different forms of model structure using induced-flow models based on either momentum or vortex theory are presented. The importance of induced-flow effects for the flight data sets used is studied. K.K.

**A90-12770**

### **FLIGHT SIMULATION MODEL VALIDATION PROCEDURE, A SYSTEMATIC APPROACH**

R. W. DU VAL, O. BRUHIS (Advanced Rotorcraft Technology, Inc., Mountain View, CA), J. M. HARRISON, and J. W. HARDING (McDonnell Douglas Helicopter Co., Mesa, AZ) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 311-326. refs  
Copyright

A flight simulation model validation procedure is applied to the FLYRT model of the U.S. Army/McDonnell Douglas AH-64 Apache attack helicopter. The procedure uses an Extended Kalman Filter/Smoother Algorithm to estimate the 'true' states and aerodynamic loads from flight test data. FLYRT is then driven by these estimated states and controls to produce comparison aerodynamic loads. Discrepancies are further isolated by comparing measured flapping to simulated flapping data. System identification techniques are applied to improve the flapping representation. The measured flapping exhibits a significant torsional flexibility effect and velocity dependence due to first harmonic inflow is also observed. The flapping model is upgraded to include these effects and the upgraded model is shown to produce good flapping correlation at low speed. Author

**A90-12773**

### **THE APPLICATION OF LINEAR MAXIMUM LIKELIHOOD ESTIMATION OF AERODYNAMIC DERIVATIVES FOR THE BELL-205 AND BELL-206**

J. H. DE LEEUW (Toronto, University, Downsview, Canada) and K. HUI (National Aeronautical Establishment, Flight Research Laboratory, Ottawa, Canada) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 369-392. refs  
Copyright

The application of parameter estimation techniques to helicopters to determine the stability and control derivatives is described. The model adopted for the helicopter is a linear fully coupled six-degree-of-freedom rigid body system. The estimation of the parameter values in this model (the stability and control derivatives) is carried out on the basis of flight tests in which the helicopter is excited by suitable control inputs. K.K.

**A90-12791**

### **HISTORY OF THE AIRFRAME. IV**

TOM RHODES Aerospace Engineering (ISSN 0736-2536), vol. 9, Oct. 1989, p. 16-21.

Copyright

A continuing development history of innovative airframe structural materials and their effects on military and experimental aircraft design practices and consequent performance levels discusses German attempts during World War II to appropriate the wooden structure technology responsible for the extraordinary performance of the British Mosquito bomber, as well as postwar confrontations with the structural problems associated with the thinner wings required for high speed flight. Also discussed are the development of honeycomb sandwich panel structures and the search for higher service-temperature metallic materials suitable for supersonic flight (as in the XB-70 bomber) and hypersonic flight (as in the X-15). O.C.

**A90-12860**

### **DEVELOPMENT AND APPLICATION OF A COMPUTER-BASED SYSTEM FOR CONCEPTUAL AIRCRAFT DESIGN**

CORNELIS BIL (Delft, Technische Universiteit, Netherlands) Delft, Delft University Press, 1988, 263 p. refs

Copyright

The design concept and implementation of an aircraft CAD system are described. The history and advantages of computer engineering in the aircraft-design field are reviewed; the steps of the aircraft-design process are outlined; and particular attention is given to a three-component software package developed at Delft University of Technology. This package comprises ADAS (aircraft design and analysis system), ADAP (an executive program to control processing of user-supplied analysis programs), and MEDUSA (a general-purpose drafting and modeling system to draw and represent design configurations). Details of the design analysis, design evaluation, weight and aerodynamic analysis, and performance prediction are discussed, and an application of the package to a short-haul passenger aircraft is shown. T.K.

**A90-12866**

### **AIRPLANE DESIGN. I - PRELIMINARY SIZING OF AIRPLANES**

JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS, Roskam Aviation and Engineering Corp., 1989, 218 p. refs  
Copyright

A rapid method for the preliminary sizing of an aircraft to a given mission specification is presented. Methods of estimating the take-off gross weight are presented as well as ways of estimating the wing area. A user's guide to preliminary aircraft sizing is provided as well. K.K.

**A90-12867**

### **AIRPLANE DESIGN. PART 2 - PRELIMINARY CONFIGURATION DESIGN AND INTEGRATION OF THE PROPULSION SYSTEM**

JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS, Roskam Aviation and Engineering Corp., 1989, 320 p. refs  
Copyright

Practical design methods for aircraft configurations are presented in an introduction for engineering students. Chapters are devoted to a step-by-step guide to configuration design, selection of the overall configuration, cockpit and fuselage layouts, and selection and integration of the propulsion system. Particular attention is given to class-I methods for the design of wing planforms, lateral control surfaces, high-lift devices, empennage, and landing gear and to class-I analysis methods for weight and balance, stability and control, and drag polars. Extensive diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

**A90-12868**

### **AIRPLANE DESIGN. PART 3 - LAYOUT DESIGN OF COCKPIT, FUSELAGE, WING AND EMPENNAGE: CUTAWAYS AND INBOARD PROFILES**



JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS,  
Roskam Aviation and Engineering Corp., 1989, 460 p. refs  
Copyright

Practical techniques for the design of aircraft subsystems are presented in an introductory text for engineering students. Chapters are devoted to the layout design of cockpit or flight deck, fuselage, wing, and empennage; propulsion-system integration; and procedures for the preliminary structural arrangement, structural-material selection, and manufacturing breakdown. Extensive diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

#### A90-12869

##### AIRPLANE DESIGN. PART 4 - LAYOUT DESIGN OF LANDING GEAR AND SYSTEMS

JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS,  
Roskam Aviation and Engineering Corp., 1989, 428 p. refs  
Copyright

A systematic approach is presented to the problem of aircraft landing gear design and aircraft systems design during the preliminary design phase. Method used to yield realistic layouts of landing gears are discussed, and data on weapons integration problems encountered during the preliminary design of military aircraft are presented. Design considerations of primary and secondary flight control systems are discussed. Layout design problems pertaining to fuel systems, hydraulic systems, electrical systems, environmental control systems, systems for cockpit instrumentation, flight management, avionics, deicing, antiicing, rain removal, and defogging, escape systems, and water and waste systems are examined. Safety and survivability are addressed. C.D.

#### A90-12870

##### AIRPLANE DESIGN. PART 5 - COMPONENT WEIGHT ESTIMATION

JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS,  
Roskam Aviation and Engineering Corp., 1989, 223 p. refs  
Copyright

Component weight estimation in aircraft design is discussed. The class I method for estimating aircraft component weights and aircraft inertias is addressed, giving sample applications to a twin engine propeller-driven aircraft, a jet transport, and a fighter. The class II method for estimating aircraft component weights is discussed, including methods for constructing V-n diagrams. The class II method for estimating the weight of the structure, powerplant, and fixed equipment is examined in detail. The location of component centers of gravity, the class II weight and balance analysis, and the class II method for estimating aircraft inertias are briefly considered. C.D.

#### A90-12871

##### AIRPLANE DESIGN. PART 6 - PRELIMINARY CALCULATION OF AERODYNAMIC, THRUST AND POWER CHARACTERISTICS

JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS,  
Roskam Aviation and Engineering Corp., 1987, 580 p. refs  
Copyright

A systematic approach is presented to the prediction of drag, installed power, and thrust, lift, pitching moment and other important stability and control data needed in preliminary design of aircraft. Different ways by which aircraft drag polars can be represented by simple mathematical models are presented, as is a method to predict the component drag breakdown and the total drag of aircraft. Methods for predicting installed thrust and power characteristics are given along with methods for predicting lift and pitching moment characteristics of aircraft with and without mechanical flaps. Prediction methods for stability, control, and hinge moment derivatives are presented. Examples are given throughout. C.D.

A90-13015\*# National Aeronautics and Space Administration.  
Langley Research Center, Hampton, VA.

##### MATERIALS AND STRUCTURES FOR HYPERSONIC VEHICLES

DARREL R. TENNEY, W. BARRY LISAGOR, and SIDNEY C. DIXON (NASA, Langley Research Center, Hampton, VA) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings. Volume 1, p. 398-415) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 953-970. Previously cited in issue 03, p. 264, Accession no. A89-13542. refs  
Copyright

#### A90-13019#

##### SIMULATIONS OF PROPELLER/AIRFRAME INTERFERENCE EFFECTS USING AN EULER CORRECTION METHOD

T. Q. DANG (Douglas Aircraft Co., Long Beach, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, Nov. 1989, p. 994-1001. Research sponsored by McDonnell Douglas Corp. refs  
Copyright

An Euler correction method has been used to study propeller effects in airframe-integration studies. In the present method, the propeller is modeled by an actuator disk with proper jump conditions prescribed along the disk. The rotational flowfield behind the propeller is analyzed using the Clebsch formulation of the Euler equations, while the remaining irrotational flowfield is determined with the full-potential method. This method has been successfully implemented into existing axisymmetric nacelle and aft-fuselage/pylon/nacelle codes to study power effects in the presence of a counter-rotating propfan of the pusher type. In the subsonic flow regime where the effect of power is prominent, comparisons of the results obtained using the present method against those of the panel method and experimental data suggest that this simple method is adequate. In the transonic flow regime, calculations indicate that power effects can increase wave drag and trigger earlier shock-induced flow separation. Author

#### A90-13224

##### NUMERICAL ANALYSIS OF VIBRATIONS OF A HELICOPTER TAIL BOOM

Z. DZYGADLO and R. OMASTA (Wojskowa Akademia Techniczna, Warsaw, Poland) Journal of Technical Physics (ISSN 0324-8313), vol. 29, no. 2, 1988, p. 257-271.  
Copyright

Results are discussed of the numerical analysis of the natural vibrations of a dynamic model structure composed of a single-rotor helicopter tail boom and the tail rotor shaft which is connected to the tail boom by means of deformable supports. The tail boom is rigidly attached to the helicopter body, which is taken to be rigid. The end portion of the tail boom is bent in the upward direction, thus creating a coupling between the flexural and torsional vibrations of the tail boom. The helicopter is assumed to be hovering, and deformable and rigid finite elements are used, where concentrated masses, elastic supports, and articulations of the shaft are taken into account. A matrix equation of the dynamic equilibrium of the structure as a whole is obtained, as well as a frequency equation. The results show that the way in which the shaft is mounted on the tail boom, particularly the stiffness of the supports, may be of essential influence on the dynamic characteristics of the system. S.A.V.

#### N90-10022#

##### Charles River Analytics, Inc., Cambridge, MA. HIERARCHICAL DAMAGE TOLERANT CONTROLLERS FOR SMART STRUCTURES Final Report, Jun. - Dec. 1988

A. K. CAGLAYAN, S. M. ALLEN, and S. J. EDWARDS Mar. 1989 68 p  
(Contract F33615-88-C-3212)  
(AD-A209422; AFWAL-TR-89-3009) Avail: NTIS HC A04/MF A01 CSCL 13/12

The research and development results are presented of the Hierarchical Damage Tolerant Controllers for Smart Structures. The major aim is the investigation and definition of a baseline architecture for a smart aerospace structure which can detect and isolate structural damage in real time and provide on-line

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

reconfiguration of the structure's control system under the detected impairment conditions. In particular, how a smart aerospace structure can be implemented as a real-time knowledge based expert system was investigated by addressing issues involved with structural knowledge representation, structural damage detection and isolation strategies and real time performance in an embedded environment. GRA

**N90-10023\*#** National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.  
**INITIAL FLIGHT QUALIFICATION AND OPERATIONAL MAINTENANCE OF X-29A FLIGHT SOFTWARE**  
MICHAEL R. EARLS and JOEL R. SITZ Sep. 1989 28 p  
Presented at the AIAA Guidance, Navigation and Control Conference, Boston, MA, 14-16 Aug. 1989  
(NASA-TM-101703; H-1558; NAS 1.15:101703; AIAA-89-3596)  
Avail: NTIS HC A03/MF A01 CSDL 01/3

A discussion is presented of some significant aspects of the initial flight qualification and operational maintenance of the flight control system software for the X-29A technology demonstrator. Flight qualification and maintenance of complex, embedded flight control system software poses unique problems. The X-29A technology demonstrator aircraft has a digital flight control system which incorporates functions generally considered too complex for analog systems. Organizational responsibilities, software assurance issues, tools, and facilities are discussed. Author

**N90-10025#** Army Aviation Engineering Flight Activity, Edwards AFB, CA.  
**AIRWORTHINESS AND FLIGHT CHARACTERISTICS TEST OF THE UH-60A BLACK HAWK HELICOPTER EQUIPPED WITH THE XM-139 MULTIPLE MINE DISPENSING SYSTEM (VOLCANO) Final Report, 1 Sep. 1987 - 28 Jan. 1988**  
RANDALL W. CASON, PAUL W. LOSIER, JOHN I. NAGATA, CHRISTOPHER J. YOUNG, and WILLIAM D. LEWIS Dec. 1988 186 p  
(AD-A210271; USAAEFA-86-12) Avail: NTIS HC A09/MF A01 CSDL 01/3

An airworthiness and flight characteristics evaluation of the UH-60A helicopter (S/N 82-23748) with the XM-139 Multiple Mine Dispensing System (VOLCANO) installed was conducted by the U.S. Army Aviation Engineering Flight Activity. The tests required 59 productive flight hours. Performance and handling qualities tests were conducted. The change in equivalent flat plate area in forward flight varied as a function of the thrust coefficient and airspeed from approximately 36 to 50 square feet. The out-of-ground effect hover capability was reduced by approximately 520 pounds. The handling qualities of the UH-60A with the VOLCANO installed were slightly degraded when compared to the normal utility configuration. Seven shortcomings were noted in this configuration. They include the large position error for this ship's airspeed system, the negative longitudinal static stability at 100 KCAS during level flight, the neutral static longitudinal stability during intermediate rated power (IRP) climbs, and the neutral to slightly negative maneuver stability above a load factor of 1.4 at 116 KCAS. GRA

**N90-10026#** Aeronautical Research Labs., Melbourne (Australia).  
**A REVIEW OF AUSTRALIAN AND NEW ZEALAND INVESTIGATIONS ON AERONAUTICAL FATIGUE DURING THE PERIOD APRIL 1987 TO MARCH 1989 Aircraft Structures Technical Memorandum**  
G. S. JOST, ed. Apr. 1989 51 p Presented at the 21st Conference of the International Committee on Aeronautical Fatigue, Jerusalem, Israel, 19-20 Jun. 1989  
(AD-A210373; ARL-STRUC-TM-506; DODA-AR-005-604) Avail: NTIS HC A04/MF A01 CSDL 20/11

This document was prepared for presentation to the 21st Conference of the International Committee on Aeronautical Fatigue scheduled to be held in Jerusalem, Israel, on June 19 and 20, 1989. A review is given of the aircraft fatigue research and associated activities which form part of the programs of the Aeronautical Research Laboratory, universities, the Civil Aviation

Authority, the Australian aircraft industry and the Defence Scientific Establishment, New Zealand. The major topics discussed include the fatigue of both civil and military aircraft structures, fatigue damage detection, analysis and repair and fatigue life monitoring and assessment. GRA

**N90-10027#** Boeing Advanced Systems Co., Seattle, WA.  
**COMPATIBILITY OF FUEL SYSTEM COMPONENTS WITH HIGH DENSITY FUEL Final Report, Apr. 1987 - Jan. 1989**  
A. F. GRENICH and A. M. JOHNSON May 1989 179 p  
(Contract F33615-87-C-2711; AF PROJ. 2480)  
(AD-A210381; WRDC-TR-89-2034) Avail: NTIS HC A09/MF A01 CSDL 21/4

Environmental and endurance tests were conducted to evaluate the performance of typical fuel system components when exposed to high density aviation turbine engine fuel. The environment tests simulated the extreme high and low temperatures encountered in hot and cold day missions. The results revealed that the high density fuel (HDF) would not have any fuel boiling or freezing problems but the pump power required for HDF was higher than for JP-4 fuel as was expected and the lower heat capacity of HDF resulted in noticeably higher heat exchanger discharge temperatures. The endurance tests revealed that the HDF would not cause abnormal wear or component leakage. Nothing in the test results suggested that current inputs to fuel system life cycle cost models should be modified if HDF is used. GRA

**N90-10028#** Army Aeromedical Research Lab., Fort Rucker, AL.  
**COCKPIT LIGHTING COMPATIBILITY WITH IMAGE INTENSIFICATION NIGHT IMAGING SYSTEMS: ISSUES AND ANSWERS**  
CLARENCE E. RASH and ROBERT W. VERONA May 1989 19 p  
(AD-A210503; USAARL-89-6) Avail: NTIS HC A03/MF A01 CSDL 17/5

Night imaging systems based on image intensification (1 sup 2) tubes are a major factor in the night operation capability of U.S. Army rotary-wing aircraft. A major problem associated with the use of these systems is the detrimental effect caused by internal cockpit lighting. Instrument lamps, caution lamps, utility lights, and other light sources inside the cockpit activate the bright source protection control circuits of the intensification tubes, thereby reducing their sensitivity to external, natural and artificial illumination. In 1986, a Tri-Service specification, MIL-L-85762, lighting, aircraft, interior, night vision imaging system compatible, was adopted to resolve the cockpit lighting problems. This specification defines the measurement instrumentation and techniques required to certify lighting components as ANVIS compatible. The specification does not address compatibility problems associated with AN/PVS-5 usage. Ongoing efforts related to MIL-L-85762 include characterization of lighting incompatibilities in current U.S. Army aircraft, implementation of programs to modify the lighting in incompatible cockpits, and certification of proposed lighting components for future aircraft systems. Additional work has been done to provide near compatible solutions to lighting problems associated with the use of AN/PVS5-systems. GRA

**N90-10031\*#** Wichita State Univ., KS. Dept. of Aeronautical Engineering.  
**ELECTRO-IMPULSE DE-ICING TESTING ANALYSIS AND DESIGN Final Report**  
G. W. ZUMWALT, R. L. SCHRAG, W. D. BERNHART, and R. A. FRIEDBERG Sep. 1988 352 p  
(Contract NAG3-284)  
(NASA-CR-4175; E-4279; NAS 1.26:4175) Avail: NTIS HC A16/MF A01 CSDL 01/3

Electro-Impulse De-Icing (EIDI) is a method of ice removal by sharp blows delivered by a transient electromagnetic field. Detailed results are given for studies of the electrodynamic phenomena. Structural dynamic tests and computations are described. Also reported are ten sets of tests at NASA's Icing Research Tunnel and flight tests by NASA and Cessna Aircraft Company. Fabrication

of system components are described and illustrated. Fatigue and electromagnetic interference tests are reported. Here, the necessary information for the design of an EIDI system for aircraft is provided. Author

**N90-10115\*** Boeing Co., Seattle, WA.

**AIRCRAFT MODAL SUPPRESSION SYSTEM: EXISTING DESIGN APPROACH AND ITS SHORTCOMINGS**

J. K. HO, T. J. GOSLIN, and C. B. TRAN /In NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 801-823 May 1989

Avail: NTIS HC A21/MF A01 CSCL 01/3

The bending of flexible body aircraft may degrade the ride comfort of passengers. This is especially noticeable towards the aft end of the aircraft (due to the relatively large tail surfaces) which may easily be excited when flying through turbulence. In addition, some aircraft may experience a front body bending mode which can be annoying to the cabin crew and first class passengers. Normally, this dominant body bending mode falls between 1 to 5 Hz. This range is easily perceived by the human body. Also, in some situations, the rigid body control law may be out of phase with the mode and aggravate the vibration. Hence, an active modal suppression system is desirable for improving the ride quality of the airplane. The size of the mathematical model, which has both the airplane rigid body and flexible characteristics, could easily exceed 100 states. The computational burden and fidelity of this large structural model is addressed. Author

**N90-10116\*** Boeing Commercial Airplane Co., Seattle, WA.

**STRUCTURAL STABILITY AUGMENTATION SYSTEM DESIGN USING BODEDIRECT: A QUICK AND ACCURATE APPROACH**

T. J. GOSLIN and J. K. HO /In NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 825-851 May 1989

Avail: NTIS HC A21/MF A01 CSCL 01/3

A methodology is presented for a modal suppression control law design using flight test data instead of mathematical models to obtain the required gain and phase information about the flexible airplane. This approach is referred to as BODEDIRECT. The purpose of the BODEDIRECT program is to provide a method of analyzing the modal phase relationships measured directly from the airplane. These measurements can be achieved with a frequency sweep at the control surface input while measuring the outputs of interest. The measured Bode-models can be used directly for analysis in the frequency domain, and for control law design. Besides providing a more accurate representation for the system inputs and outputs of interest, this method is quick and relatively inexpensive. To date, the BODEDIRECT program has been tested and verified for computational integrity. Its capabilities include calculation of series, parallel and loop closure connections between Bode-model representations. System PSD, together with gain and phase margins of stability may be calculated for successive loop closures of multi-input/multi-output systems. Current plans include extensive flight testing to obtain a Bode-model representation of a commercial aircraft for design of a structural stability augmentation system. Author

**N90-10119\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**THE ACTIVE FLEXIBLE WING AEROSERVOELASTIC WIND-TUNNEL TEST PROGRAM**

THOMAS NOLL and BOYD PERRY /In its Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 903-941 May 1989

Avail: NTIS HC A21/MF A01 CSCL 01/3

For a specific application of aeroservoelastic technology, Rockwell International Corporation developed a concept known as the Active Flexible Wing (AFW). The concept incorporates multiple active leading-and trailing-edge control surfaces with a very flexible wing such that wing shape is varied in an optimum manner resulting in improved performance and reduced weight. As a result of a cooperative program between the AFWAL's Flight

Dynamics Laboratory, Rockwell, and NASA LaRC, a scaled aeroelastic wind-tunnel model of an advanced fighter was designed, fabricated, and tested in the NASA LaRC Transonic Dynamics Tunnel (TDT) to validate the AFW concept. Besides conducting the wind-tunnel tests NASA provided a design of an Active Roll Control (ARC) System that was implemented and evaluated during the tests. The ARC system used a concept referred to as Control Law Parameterization which involves maintaining constant performance, robustness, and stability while using different combinations of multiple control surface displacements. Since the ARC system used measured control surface stability derivatives during the design, the predicted performance and stability results correlated very well with test measurements. Author

**N90-10860\*** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

**FLIGHT TEST TECHNIQUES**

Jul. 1989 419 p In ENGLISH and FRENCH Symposium held at Edwards AFB, CA, 17-20 Oct. 1988

(AGARD-CP-452; ISBN-92-835-0509-3) Copyright Avail: NTIS HC A18/MF A03

It is important that the flight test community meet regularly so that techniques for flight test, instrumentation and data analysis can be disseminated to ensure safe, efficient, and timely testing. The number of systems submitted for airborne trials and testing is increasing. The major development and test challenge common to most aircraft is that of avionic/software subsystems development and integration. Systems and applications include programmable signal process radars, integrated flight, fire and propulsion systems, multifunction pilot displays, and other on-board software-intensive systems. The focus was on the means of reducing the overall cost of test and development within defence program. Ground based simulation offers the potential for saving many test flying hours in the area of system integration. It is an indispensable tool for system failure analysis for sophisticated avionics of all types.

**N90-10861\*** Naval Air Test Center, Patuxent River, MD. Advanced Tactical Aircraft Program.

**US NAVY PRINCIPAL SITE TESTING CONCEPT AND THE F-18**

JOE L. DUNN /In AGARD, Flight Test Techniques 4 p Jul. 1989

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In 1975, a decision was made to conduct the F-18 Full Scale Development (FSD) Program at a primary Navy location, the U.S. Naval Air Test Center (NAVAIRTESTCEN). Previous FSD programs had utilized multiple test locations which resulted in significant program duplication from a facilities, logistics, and test data viewpoint. The principal site concept provides for a primary Navy location where all test assets are co-located. These assets include developmental aircraft, contractor and Navy test personnel, maintenance personnel, and all test equipment. The success of the F-18 principal site testing program paved the way for the AV-8B and LAMPS MK 3 programs at the NAVAIRTESTCEN. The principal site concept has had excellent benefits for the U.S. Navy in terms of improved test aircraft utilization, better visibility into the contractor's test program, elimination of redundant testing by utilizing a common data base, and improved utilization of government test facilities. From the Navy's T and E community viewpoint, it is preferable to conduct the programs at a Navy test activity. Due to program funding constraints, this may not always be possible. With the F-14D and A-6F upgrade programs, the testing is being conducted at the contractor's facility as opposed to a Navy facility. In this case, the Navy has established a Navy Test Team on-site and is participating actively with the contractor during the FSD programs. The impact of the principal site testing concept will be examined from the perspective of both the Navy and the contractor in terms of impact on the individual organizations. Author

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

**N90-10862#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. for Flight Mechanics.

### **ATTAS FLIGHT TESTING EXPERIENCES**

H.-H. LANGE, D. ROHLF, A. ZACH, and H.-L. MEYER /in AGARD, Flight Test Techniques 14 p Jul. 1989

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An overview of recent development and flight test experiences of the DFVLR's flight test vehicle Advanced Technologies Testing Aircraft System (ATTAS) equipped with a digital fly-by-wire/light flight control system is presented. System design, multiprocessor communication management, parallel data processing, redundancy management as well as software development and validation are summarized. Further, the role of ground based system simulation for development and testing, flight test procedures and interesting flight test results are dealt with in several examples. Author

**N90-10863#** I.A.M. Rinaldo Piaggio, Finale Ligure (Italy).

### **P-180 AVANTI: PROJECT AND FLIGHT TEST PROGRAM COMPREHENSIVE OVERVIEW**

R. DEPOMPEIS and E. TRAINI /in AGARD, Flight Test Techniques 28 p Jul. 1989

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Among the turboprops in advanced flight testing phase, the Piaggio P-180 AVANTI possesses exciting features. Very unconventional shape, characterized by 3 lifting surfaces, pusher props, mid-wing very rearback mounted, is coupled with outstanding speed and range performances. The project and flight test programs planning has required much care for the peculiar characteristic of the aircraft. Areas of extensive in-flight investigation were: flutter expansion; stability and control at high angle of attack; laminar flow investigation; flap system tuning; and propeller stress. The focus is on the P-180 project and flight test programs presenting the project concepts and the test results achieved to date. The flight test program, actually in the certification phase, has achieved more than 600 flight hours and RAI/FAA initial certification is expected for mid 1989. Author

**N90-10864#** Airbus Industrie, Blagnac (France). Dept. Essais en Vol.

### **A320 FLIGHT TESTS: PARTICULARITIES AND INNOVATIONS [ESSAIS EN VOL A320]**

GERARD GUYOT /in AGARD, Flight Test Techniques 5 p Jul. 1989 In FRENCH

Copyright Avail: NTIS HC A18/MF A03

The general architecture of the electronic flight control system for the A320 Airbus is described and the functions of the SPATIAL system are outlined. Protection against electromagnetic radiation is addressed and related ground and flight tests are briefly described. Author

**N90-10865#** British Aerospace Public Ltd. Co., Preston (England). Military Aircraft Div.

### **THE EXPERIMENTAL AIRCRAFT FLIGHT TEST PROGRAMME**

R. A. HARTLEY /in AGARD, Flight Test Techniques 11 p Jul. 1989

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The Experimental Aircraft Program has grown out of the studies carried out over the last decade to investigate the needs for the next generation of fighter. These studies resulted in the definition of a large number of new technologies for which it was recognized that there would be significant benefits to be gained by their integration into a demonstrator aircraft. The objectives and progress of the flying program are described for this demonstrator and how it has lead on to the European Fighter Aircraft. Author

**N90-10866\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **REAL-TIME FLIGHT TEST ANALYSIS AND DISPLAY TECHNIQUES FOR THE X-29A AIRCRAFT**

JOHN W. HICKS and KEVIN L. PETERSEN /in AGARD, Flight Test Techniques 17 p Jul. 1989

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The X-29A advanced technology demonstrator flight envelope expansion program and the subsequent flight research phase gave impetus to the development of several innovative real-time analysis and display techniques. These new techniques produced significant improvements in flight test productivity, flight research capabilities, and flight safety. These techniques include real-time measurement and display of in-flight structural loads, dynamic structural mode frequency and damping, flight control system dynamic stability and control response, aeroperformance drag polars, and aircraft specific excess power. Several of these analysis techniques also provided for direct comparisons of flight-measured results with analytical predictions. The aeroperformance technique was made possible by the concurrent development of a new simplified in-flight net thrust computation method. To achieve these levels of on-line flight test analysis, integration of ground and airborne systems was required. The capability of NASA Ames Research Center, Dryden Flight Research Facility's Western Aeronautical Test Range was a key factor to enable implementation of these methods. Author

**N90-10867#** Avions Marcel Dassault-Breguet Aviation, Istres (France).

### **FLIGHT TEST TECHNIQUES ADOPTED BY AVIONS MARCEL DASSAULT-BREGUET AVIATION**

JEAN COSTARD /in AGARD, Flight Test Techniques 35 p Jul. 1989 In FRENCH and ENGLISH

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The ever-increasing complexity of aircraft and systems entailed, in parallel, a very substantial increase in development tests, and consequently a rise of cost. Avions Marcel Dassault-Breguet Aviation (AMD-BA) have adopted techniques enabling to reduce the number of flight tests for the benefit of less expensive ground tests: flights must be saved for demonstration with the aim of qualification. These techniques allowed to keep in control of data acquisition rates while preserving reasonable means of computation and facilitating analysis. Author

**N90-10868#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.

### **GRATE: A NEW FLIGHT TEST TOOL FOR FLYING QUALITIES EVALUATION**

R. KOEHLER, E. BUCHACKER, and D. J. BIEZAD (Air Force Inst. of Tech., Wright-Patterson AFB, OH.) /in AGARD, Flight Test Techniques 18 p Jul. 1989

Copyright Avail: NTIS HC A18/MF A03

A flight test tool was worked out by DFVLR for flying quality evaluations of ground attack tracking phases. This Ground Attack Technique (GRATE) was proven in test flights of the German Federal Armed Forces Engineering Center for Aircraft and was integrated in the Large Amplitude Multimode Aerospace Research Simulator (LAMARS) of Air Force Wright Aeronautical Laboratories (AFWAL) in Dayton. The German/U.S. cooperation was supported by the Memorandum of Understanding (MoU) Flight Control Concepts. A description of the flight test method and of the pilot's role and ratings is given. Head-up-display films evaluated to determine a so called align-time and a circular error probability (CEP). The influence of different test conditions on the mission parameters were investigated. The results of the numerical analysis and the pilot ratings were compared. The determined gradients show the sensitivity of a pilot rating to the mission parameters. In this context a configuration with slight PIO-tendencies is discussed. Simulator tests have shown that the technique is an effective tool for unmasking aircraft handling problems. The effects caused by different turbulence levels on pilot ratings were found to be small in comparison to conventional methods. Author

**N90-10869#** Aeritalia S.p.A., Caselle Torinese (Italy). Combat Aircraft Group.

### **IN FLIGHT RELIGHT TESTS ON AM-X SINGLE ENGINE FLY-BY-WIRE AIRCRAFT**

G. MENSIO and G. GAMALERO /in AGARD, Flight Test Techniques

17 p Jul. 1989

Copyright Avail: NTIS HC A18/MF A03

The in-flight relight evaluation of a single engine aircraft could be considered one of the more interesting aspects of flight testing. When the engine is intentionally shut down in flight to attempt the relight, possibility of an unsuccessful one must always be taken into account and therefore a flame out landing must be contemplated, otherwise the aircraft is lost. This event may be particularly serious on a fly-by-wire aircraft on which the loss of the engine and all its driven accessories will make control very difficult if not impossible. Therefore, the planning and the execution of this kind of test not only concerns the propulsion aspects, but involves all the aircraft, because full evaluation (both theoretic and flight test) of aircraft and systems performance and reliability in engine out condition must be carried out in advance of the actual relight tests. Besides the relight evaluation must be carried out as early as possible on the program to allow safe performing of those tests that may cause a flame out. All the activities carried out by AERITALIA Flight Test Department in connection with relight tests of AM-X are described and may therefore be looked upon as a reference for smooth test planning and execution. Author

**N90-10870#** Technische Univ., Brunswick (Germany, F.R.). Inst. for Flight Guidance and Control.

#### FLIGHT TEST RESULTS OF A COMPLEX PRECISE DIGITAL FLIGHT CONTROL SYSTEM

GUNTHER SCHAEENZER /in AGARD, Flight Test Techniques 9 p Jul. 1989

Copyright Avail: NTIS HC A18/MF A03

The presented flight control systems consist of an open loop control system and a more conventional state vector feed back closed system. The open loop actuator control includes a quasistationary aircraft model and a full state command model. For the flight tests of this control system, the minimization of the state vector error was the basic target. To improve the flight test quality, an onboard real time wind and turbulence measurement system has been used. The flexible flight test instrumentation including sensors and computers will be described and some typical flight test results will be demonstrated. Author

**N90-10872#** Air Force Flight Test Center, Edwards AFB, CA.

#### THE AIR FORCE FLIGHT TEST CENTER FLIGHT TEST SAFETY PROGRAM

KELLY J. ADAMS and MARK R. CRAWFORD /in AGARD, Flight Test Techniques 10 p Jul. 1989

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The success of the AFFTC flight test safety program is based on: (1) careful attention to the safety planning aspects of testing by each program manager, with thorough review of any applicable formal safety analyses, investigation of more experienced personnel in the subject of test and review of past programs of similar nature for successful and faulty safety planning; (2) management review of the safety aspects, endorsement and approval of every new and modified test program; (3) the establishment of a staff system safety division which facilitates an independent review of every new and modified test program; (4) flexibility in the safety documentation when programmatic changes occur; (5) attention to test disciplines of control room procedures, conduct and communication; and (6) the presence of a Unit System Safety Officer at each project to review the safety documentation for completeness and accuracy. Author

**N90-10874#** Centre d'Essais en Vol, Bretigny-sur-Orge (France).

#### LESSONS LEARNED FROM THE INTEGRATION OF FLIGHT SYSTEMS [LES ENSEIGNEMENTS DE L'INTEGRATION DES SYSTEMES EMBARQUES]

JACQUES TRESSSET /in AGARD, Flight Test Techniques 9 p Jul. 1989 In FRENCH

Copyright Avail: NTIS HC A18/MF A03

Suggestions for minimizing overall costs and delays of flight tests related to the integration of aircraft flight systems are

presented. Experiences with the ACT Rafale program are discussed. Author

**N90-10875#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.

#### FLIGHT TESTING OF THE TORNADO TERRAIN FOLLOWING SYSTEM

THOMAS FLECK /in AGARD, Flight Test Techniques 12 p Jul. 1989

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The flight test activities on the assessment of the Tornado Terrain Following System are reviewed. Extensive hardware and pilot in the loop simulation, a stepwise approach to the lowest height and proceeding from VMC to IMC kept the risk at a minimum level. For a demonstration of system performance a method of comparing simulation was applied that considers avionic parameters, aerodynamic parameters, and flight control data. Special emphasis was placed on system integrity and flight safety, including human factors of the aircrew. Today, after having absolved more than 200 successful test flights and rectified a considerable number of problems, the system was adopted by the services and is a substantial part of the low level missions. Author

**N90-10877#** Aerospace Engineering Test Establishment, Cold Lake (Alberta).

#### CF 18 480 GALLON EXTERNAL FUEL TANK STORES CLEARANCE PROGRAM

DOUGLAS N. KOBAYASHI and MIRKO B. ZGELA /in AGARD, Flight Test Techniques 15 p Jul. 1989

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The Canadian Government has embarked on a program with Canadian industry to manufacture a composite 480 gallon external fuel tank (EFT) designed for the CF-18 aircraft by McDonnell Aircraft Company (McAir). Prior to commencing the production phase of the program, the Aerospace Engineering Test Establishment (AETE) of the Canadian Forces (CF) was tasked to support McAir in the flight test certification of the 480 EFT on the inboard wing stations of the CF-18. The main objective was to provide a proof of concept flight demonstration as well as establish an operational flight envelope for the carriage and jettison of the 480 EFT with and without adjacent stores. The certification process involved a progressive series of analyses, laboratory tests, wind tunnel tests, ground tests and flight tests. As the CF flight test authority, AETE was responsible for conducting all flight testing activities including flutter, active oscillation control (AOC), structural mode interactions (SMI), stability and control, structural carriage loads, separation/jettison, and dynamic response testing. An overview is presented of the the joint CF-18 480 EFT stores clearance program and its main emphasis is in describing the analyses and tests performed during the ground vibration testing, flutter, AOC, SMI and carriage loads phases. The aircraft instrumentation and the qualification/ground tests performed on the tanks prior to the beginning of flight test activities are briefly discussed. Test results and the technical problems encountered during the program are also presented. Author

**N90-10882#** Army War Coll., Carlisle Barracks, PA. Military History Inst.

#### FLIGHT TESTING AND FLIGHT RESEARCH: FROM THE AGE OF THE TOWER JUMPER TO THE AGE OF THE ASTRONAUT

RICHARD P. HALLION /in AGARD, Flight Test Techniques 13 p Jul. 1989

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Since the beginning of flight, aerospace vehicle design has depended upon data gathered from the performance of actual flight vehicles. This flight testing and flight research process has led to today's air-and-space-craft, and points the way for future flight. Within this process, the flight test planner, test pilot, and flight test engineer occupy positions of critical importance. A review of the history of flight testing and flight research indicates that both were traditionally characterized by a professional approach emphasizing the derivation and utilization of methodologies to best enable investigators to acquire a maximum amount of information

as quickly as is consistent with safety. As the technological sophistication of aircraft systems has increased, so, too, has the necessity for improving, modifying, and adding to the capabilities of the flight testing and flight research process. This pattern may be expected to hold true for the subsequent development of future advanced aerospace vehicle systems. Author

**N90-10884#** National Aerospace Lab., Amsterdam (Netherlands).

## **FLIGHT TESTING IN THE NETHERLANDS: AN OVERVIEW**

J. T. M. VANDOORN and R. L. VANDERVELDE in AGARD, Flight Test Techniques 25 p Jul. 1989  
Copyright Avail: NTIS HC A18/MF A03

An overview is given for the flight test activities and capabilities in The Netherlands. A general description of the flight test programs of the last decades with civil and military aircraft, helicopters and research aircraft are given. Some of the highlights of the more recent programs are presented, i.e., the type certification of the Fokker 50 and Fokker 100 civil transport aircraft, evaluation and certification trials with the military F16 fighter aircraft, helicopter-ship compatibility testing and the determination of the mathematical model of the Cessna Citation 500 for a Phase 2 flight simulator. Furthermore a short description is given of the flight test instrumentation and flight test techniques that have become available in The Netherlands during the last decade. Author

**N90-10888#** Aeronautical Research Labs., Melbourne (Australia).

## **THE SPINNING OF AIRCRAFT: A DISCUSSION OF SPIN PREDICTION TECHNIQUES INCLUDING A CHRONOLOGICAL BIBLIOGRAPHY**

COLIN A. MARTIN Aug. 1988 45 p  
(ARL-AERO-R-177; AR-005-530) Avail: NTIS HC A03/MF A01

Aircraft spinning is an important area of design for general aviation and military aircraft, and has been so, since the early days of aviation. In many of the major aeronautical laboratories in the world, aircraft spinning has been the subject of intensive periods of research. However, the resulting design criteria are still only adequate for predicting gross trends in aircraft spin behavior. To enable flight testing to proceed with confidence and to minimize modifications during flight development, most major aircraft development programs include extensive scale-model spin testing. Here, the development of these techniques and their application for spin prediction are discussed. Author

**N90-10889\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

## **INTEGRATED MULTIDISCIPLINARY DESIGN OPTIMIZATION OF ROTORCRAFT**

HOWARD M. ADELMAN and WAYNE R. MANTAY (Army Aviation Systems Command, Hampton, VA.) Jul. 1989 13 p Presented at the AIAA/AHS/ASSEE 1989 Aircraft Design and Operations Meeting, Seattle, WA, 31 Jul. - 2 Aug. 1989 Previously announced in IAA as A89-49478

(NASA-TM-101642; NAS 1.15:101642; AVSCOM-TM-89-B-008)  
Avail: NTIS HC A03/MF A01 CSCL 01/3

The NASA/Army research plan for developing the logic elements for helicopter rotor design optimization by integrating appropriate disciplines and accounting for important interactions among the disciplines is discussed. The optimization formulation is described in terms of the objective function, design variables, and constraints. The analysis aspects are discussed, and an initial effort at defining the interdisciplinary coupling is summarized. Results are presented on the achievements made in the rotor dynamic optimization for vibration reduction, rotor structural optimization for minimum weight, and integrated aerodynamic load/dynamics optimization for minimum vibration and weight. IAA

## **AIRCRAFT INSTRUMENTATION**

Includes cockpit and cabin display devices; and flight instruments.

**A90-10507\*#** Bolt, Beranek, and Newman, Inc., Cambridge, MA.

## **INTELLIGENT SITUATION ASSESSMENT AND RESPONSE AIDING IN FLIGHT EMERGENCIES**

EVA HUDLICKA, KEVIN CORKER, MICHAEL CRAMER, DAVID YOUNG, and SHELDON BARON (BBN Systems and Technologies Corp., Cambridge, MA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 257-266. refs  
(Contract NAS1-18788)

(AIAA PAPER 89-2999) Copyright

A knowledge-based pilot aiding system which performs situation assessment and response aiding is described. The system uses a causal model of the flight domain to both simulate the effects of identified failures on flight and to derive responses during emergencies. The model represents information at two levels of abstraction: Boolean, which simply states whether a subsystem or aircraft component is normal or abnormal, and qualitative, which expresses the subsystem or component status as one of several qualitative values, such as increasing, decreasing, or stable. Author

**A90-10524#**

## **PILOT'S ASSOCIATE - A PERSPECTIVE ON DEMONSTRATION 2**

CARL S. LIZZA (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 386-394. refs  
(AIAA PAPER 89-3023)

The Demonstration 2 stage of the Pilot's Associate program is briefly reviewed with particular reference to the approaches used, the functional capabilities, implementation successes and failures, and lessons learned from this experiment in the application of complex real-time artificial intelligence systems. The program has proven the benefits of rapid prototyping within a structured, well-disciplined approach. Of particular importance is the operational utility of a Pilot's Associate in improving the decision-making capability of the pilot of an advanced aircraft. As the program continues, emphasis is shifting toward addressing the requirements of a more near-term, embedded-avionics application of intelligent systems. V.L.

**A90-10535#**

## **AN OBJECTIVE METHODOLOGY FOR DEFINITION AND EVALUATION OF ADVANCED AVIONICS ARCHITECTURES**

S. RAHMANI (Rockwell International Corp., Space Transportation Systems Div., Downey, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 471-477.  
(AIAA PAPER 89-3035) Copyright

A methodology has been developed for definition of advanced avionics architectures and successfully applied to develop an architecture for an avionics vehicle. The avionics system consists of the following subsystems: software; data-processing hardware; guidance, navigation, and control; communications and tracking; test and checkout; and instrumentation. The methodology consists of four steps: (1) definition of candidate data-management system architectures, (2) definition of candidate avionics architectures, (3) architecture evaluation from a subsystem viewpoint, and (4) architecture evaluation and selection from avionics-system



viewpoint. The methodology is applied to a generic avionics system. Results include a set of candidate avionics architectures and the data associated with their ranking and characteristics. Author

#### A90-10580#

##### **BENCHMARKING BLACKBOARDS TO SUPPORT COCKPIT INFORMATION MANAGEMENT**

DAVID M. BLEVINS, BRAD S. MILLER (Boeing Advanced Systems, Seattle, WA), and LARRY S. BAUM (Boeing Computer Services, Seattle, WA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 827-834. refs  
(AIAA PAPER 89-3095) Copyright

Benchmark studies were carried out on two implementations of a cockpit information management system. In each case, three different data support structures are used to determine the performance effects of changing the underlying data representation in a specific blackboard system implementation. The evolution of Erasmus is described as well as the evolution of the pilot vehicle interface application, and the Erasmus support systems. K.K.

#### A90-10581#

##### **PROBLEM FOCUS MECHANISMS FOR COCKPIT AUTOMATION**

RICHARD STENERSON, KIMBERLY KAISER (Boeing Advanced Systems, Seattle, WA), and LAWRENCE BAUM (Boeing Computer Services, Seattle, WA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 835-842. refs  
(AIAA PAPER 89-3096) Copyright

An extension of the Erasmus blackboard which captures crew preferences and knowledge of air crew tasks in top-level logic called the meta level and knowledge of the processes and state of individual air crew tasks in task-level logic is described. A comparison is made with current Erasmus control logic. The automation of task support is described as well as limitations of task support automation, and the current control capability of Erasmus. K.K.

#### A90-10583#

##### **THE BATTLE CAPTAIN EXPERT SYSTEM - A MISSION MANAGEMENT DECISION SUPPORT SYSTEM FOR ATTACK HELICOPTER OPERATIONS**

ALETA M. GLEASON (United Technologies Corp., Sikorsky Aircraft Div., Stratford, CT) and HOWARD R. SMITH (United Technologies Research Center, East Hartford, CT) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 850-858. refs  
(AIAA PAPER 89-3098) Copyright

The Battle Captain's role is discussed as well as techniques used to develop the expert system components which have been developed to date. Knowledge representation issues and strategies are shown to be critical for providing a baseline expert system design with potential to evolve into an aircraft-embedded application. The Battle Captain Expert System is an interactive expert system which demonstrates to an evaluator how expert system technology can enhance the mission management function in attack helicopter operations. The technical approach for the development of the Battle Captain Expert System was an AI approach to software development. K.K.

A90-10586\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

##### **REAL-TIME FAULT MONITORING FOR AIRCRAFT APPLICATIONS USING QUANTITATIVE SIMULATION AND EXPERT SYSTEMS**

PAUL C. SCHUTTE (NASA, Langley Research Center, Hampton, VA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC,

American Institute of Aeronautics and Astronautics, 1989, p. 876-885. refs

(AIAA PAPER 89-3103) Copyright

A fault monitoring concept called MONITAUR, which has been developed for aircraft applications at NASA-Langley, is described. MONITAUR was designed to provide a high-quality situational assessment of aircraft subsystems to other onboard software systems in abnormal situations. A nonreal-time implementation of MONITAUR was developed on a Symbolics 3650 Lisp Machine. Issues which must be addressed in the further development of MONITAUR are discussed. K.K.

#### A90-10985

##### **ANTENNA SIDELobe REQUIREMENTS FOR THE MEDIUM PRF MODE OF AN AIRBORNE RADAR**

GUY V. MORRIS (Georgia Institute of Technology, Atlanta) Microwave Journal (ISSN 0192-6225), vol. 32, Sept. 1989, p. 121, 122, 124 (5 ff.). refs

Copyright

Characteristics are presented of the medium pulse repetition frequency (PRF) mode, which has become the most used mode of the modern airborne pulsed Doppler radar. The basic principles of the medium PRF mode are reviewed, and an approximation for rapid synthesis of the antenna sidelobe requirements for optimum system performance are presented. It is concluded that target obscuration by mainlobe clutter is reduced using multiple PRFs, and target obscuration by sidelobe clutter is reduced by reducing the antenna sidelobes, pulse width, and Doppler filter bandwidth. Antenna sidelobe reduction techniques, however, increase the width of the mainlobe clutter spectrum, and sidelobe control alone is not sufficient to prevent detection of large structures, such as water towers and metal buildings, through the sidelobes at short ranges. S.A.V.

#### A90-11201

##### **FIBER OPTIC SMART STRUCTURES AND SKINS; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 8, 9, 1988**

ERIC UDD, ED. (McDonnell Douglas Astronautics Co., Huntington Beach, CA) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 986), 1989, 214 p. For individual items see A90-11202 to A90-11225.

(SPIE-986) Copyright

An overview of fiber-optic smart structures and skins is presented. Particular papers are presented on fiber-optic sensors for smart aerospace structures, full-field analysis of modal domain sensor signals for structural control, composite cure monitoring with IR-transmitting optical fibers, and the development of porous glass-fiber optical sensors. B.J.

#### A90-11202

##### **OVERVIEW OF FIBER OPTIC SMART STRUCTURES FOR AEROSPACE APPLICATIONS**

ERIC UDD (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 2-5. refs

Copyright

Aerospace applications of fiber optic smart structures are reviewed. Fiber optic sensor technology offers the possibility of reduced manufacturing cost of composite materials through better control and yield; nondestructive evaluation of parts to check for flaws; and low-cost and light-weight sensing systems that may perform key functions in vehicle health monitoring and flight control for future aerospace vehicles. C.E.

#### A90-11203

##### **FIBER OPTIC SENSORS FOR COMPOSITE MONITORING**

W. B. SPILLMAN, JR. (Hercules Aerospace Co., Aircraft Systems Div., Vergennes, VT) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988.



Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 6-11.

Copyright

The advantages of applying fiber optic sensing techniques to the manufacturing, testing, and in-service real-time health monitoring of composite structures are reviewed. The types of sensors which could be used are discussed, with a focus upon the benefits that they would provide for smart skins applications. The design of composite structures with embedded fiber optic sensors offers the potential of lower cost and higher quality products. Technical diagrams are included. C.E.

### A90-11205

#### AIR FORCE SMART STRUCTURES/SKINS PROGRAM OVERVIEW

C. J. MAZUR, G. P. SENDECKYJ, and D. M. STEVENS (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 19-29. refs

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Major improvements in a number of technologies such as smart structures and smart skins are considered for the successful development of smart aerospace vehicles. Emphasis is placed on the capabilities and deficiencies of current fiber optic sensors. Areas requiring research and development to achieve full potential fiber optic sensors for smart structures and skins are discussed, including advanced computers and communication/power transmission links. C.E.

### A90-11208

#### FIBER OPTIC SENSOR SYSTEMS FOR SMART AEROSPACE STRUCTURES

P. D. DEAN, R. O. CLAUS, D. A. MARTIN, and D. TRITES (Lockheed Aeronautical Systems Co., Burbank, CA) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 55-61. refs

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The paper discusses the possibilities of adding smarts to structural components, noting the impact of optical fiber sensors and associated system requirements and related issues. From a systems point of view, a smart structure has a number of specific elements whose functions are critically dependent on the end use of the sensor information. The basic system consists of a sensor subsystem, a signal conditioning subsystem, a communications subsystem, and a decision-making subsystem. The use of optical fibers in the sensor system is explicitly discussed, especially in connection with high performance military aircraft as well as vehicles travelling at sustained hypersonic speeds (above Mach 5). C.E.

### A90-11210

#### OPTICAL FIBER SENSING CONSIDERATIONS FOR A SMART AEROSPACE STRUCTURE

DAVID W. JENSEN (Pennsylvania State University, University Park) and RICHARD W. GRIFFITHS (G2 Corp., Pacific Palisades, CA) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 70-76. Research supported by USAF. refs

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In this paper, many of the critical issues which affect the application of embedded fiber-optic sensors for smart structures applications are identified, discussed, and - to a limited extent - experimentally verified. In particular, fabrication, durability, and characterization issues are addressed. The fabrication procedures for embedding these sensors into advanced composite components have been refined. This has been demonstrated with the successful fabrication of a 1.5 inch diameter by 58 inch long composite tube with an embedded fiber-optic pressure sensor. Preliminary characterization results using an optical time-domain reflectometer are presented. Author

### A90-11221

#### PRODUCIBILITY AND LIFE CYCLE COST ISSUES IN APPLICATIONS OF EMBEDDED FIBER OPTIC SENSORS IN SMART SKINS

MICHAEL D. BARRICK (LTV Corp., Military Aircraft Div., Dallas TX) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 171-179.

Copyright

Fiber optic sensors embedded in composite aircraft skins offer the capability of detecting physical parameters with extremely high sensitivity and bandwidth in unique intralaminar locations. The ultimate usage extent of these sensors will be determined by the cost savings provided through the availability of the additional sensed information versus life cycle costs in terms of producibility and maintainability. Over the lifetime of the aircraft, maximum sensor array utility is achieved by multiple uses such as structural integrity monitoring, multi-color, low and high speed data buses, and new types of air data sensors. These sensors have a reliable interconnection system and are designed with adequate redundancy so that graceful degradation of the sensor array can be achieved. Reliability, maintainability, and supportability issues in applications of embedded fiber optic sensors in smart skins are discussed. C.E.

### A90-11660

#### OPTIC MULTIPLEX FOR AIRCRAFT SENSORS - ISSUES AND OPTIONS

WALTER L. GLOMB, JR. (United Technologies Research Center, East Hartford, CT) and D. VARSHNEYA (Teledyne Ryan Electronics, San Diego, CA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 2-10. refs

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Recent studies have shown that the advantages of fiber-optic sensors in aircraft flight control are realized at the system level, not in the sensors or components themselves. These advantages derive from a fiber-optic systems approach in which the number and variety of cables and interface circuits are reduced by optical multiplexing. This paper describes a top-down approach to sensor system design which emphasizes selection of a network architecture to maximize system-level criteria prior to specification of sensor types. A key aspect of this design is multiplexing arrays of sensors through a common electrooptical interface. The most desirable multiplexing technique and network architecture would be one which is compatible with all or at least the greatest number of sensors while reducing system size and weight. Author

### A90-11661

#### A REVIEW OF FIBER OPTIC FLIGHT EXPERIENCE - PAST PROBLEMS, FUTURE DIRECTION

WILLIAM R. LITTLE (Eldec Corp., Sensing Systems Div., Bothell, WA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 11-17. refs

Copyright

The available flight test data on fiber optic hardware on various airframes are briefly reviewed with emphasis on aspects related to the installability, maintainability, and in-service reliability of this technology. The critical areas needing further investigation and improvement are identified, such as the need for simpler and better connectors, cable/harness concepts, and the need for simpler and more effective tools and procedures. Some goals for future developments in this field are outlined. V.L.

### A90-11663

#### WAVELENGTH DIVISION MULTIPLEXED FIBER OPTIC SENSORS FOR AIRCRAFT APPLICATIONS

NORRIS E. LEWIS and MICHAEL B. MILLER (Litton Industries, Poly-Scientific Div., Blacksburg, VA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept.

6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 29-37. refs  
Copyright

This paper describes the design and performance of a sensor system based on passive fiber optic sensors utilizing the principle of wavelength division multiplexing. The system is discussed in relation to the requirements of aircraft applications. The requirements on the source, sensor and detection circuits are outlined and a detailed power budget for a 12 bit rotary sensor is given. Measured performance of the various components is presented, along with a discussion of the environmental conditions found in various application areas within the aircraft. The wavelength sensing technique becomes the basis for a common sensor interface, and various techniques are described to provide capability for multiplexing many sensors onto one common interface.

Author

#### A90-11664

##### TOWARD FLY-BY-LIGHT AIRCRAFT

JOHN R. TODD (Douglas Aircraft Co., Long Beach, CA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 38-42. Copyright

The current status of fiber-optic components and systems for aircraft is reviewed, and efforts to develop standards and standardized test procedures are discussed. In particular, attention is given to three recently implemented flight test systems, including a fiber-optic passenger entertainment system, a fiber-optic aileron position sensing system, and a fiber-optic wheel speed sensing system. The discussion also covers some aspects of the manufacturing and installation of fiber-optic components and an overview of fiber-optic systems that are currently being developed, including an integrated fiber-optic flight control system.

V.L.

#### A90-12195

##### MAGNETIC RECORDING ON BOARD AIRCRAFT

JEAN COSTARD and PHILIPPE PATUREAU (Avions Marcel Dassault-Breguet Aviation, Istres, France) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 315-328. In English and French. Copyright

It is noted that the recording limits have been reached for the conventional WB 2 analog recorders. Thus, two other types of recorders must be added for which a standard must be established: (1) a 28-track combined FM, parallel recorder and (2) a high-density digital recorder. Both of these recorders are required to have an error correcting code. Results are presented on the testing of the Rafale, the Mirage 2000 N, and the Mirage Export.

B.J.

#### A90-12198

##### PROSPECTS OF ONBOARD MAGNETIC TAPE RECORDING DURING FLIGHT TESTS [PERSPECTIVES DE L'ENREGISTREMENT SUR BANDE MAGNETIQUE A BORD DANS LES ESSAIS EN VOL]

J. F. SULZER (Schlumberger Industries, Velizy-Villacoublay, France) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 349-358. In French. Copyright

The multiplication of sensors, the search for higher precision, and new digital equipment, among other factors, have led to an increase in the volume of data that must be recorded during flight tests; this has been accompanied by a progressive substitution of analog signals by digital messages. It is shown how modern onboard magnetic recording responds to these factors in terms of capacity and environmental conditions. Particular attention is given to the turning-head recording principle and to the MIL-STD-2179 interchangeability standard.

B.J.

#### A90-12202

##### TESTING FACILITY AND PROCEDURE OF THE ATTAS ON-BOARD DATA ACQUISITION SYSTEM

M. F. KEVENOGLU and H.-J. KLEWE (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 389-402. Copyright

A versatile, highly accurate, and testable data acquisition system has been developed for the new Advanced Technologies Testing Aircraft System (ATTAS) in operation at DFVLR in Braunschweig. The system consists of signal conditioning (SC) units and is controlled by an SC master controller with integrated PCM encoder; it processes software-controlled parameters and adaptable signal inputs. It is shown that the ATTAS measurement system incorporating a test and calibration system (TACS) and SC with built-in test equipment enables very fast computer-controlled functional checks of the signal-conditioned system and associated sensors as a preflight test.

B.J.

#### A90-12204

##### A COMFORTABLE AND UNIVERSAL DATA-ACQUISITION-SYSTEM FOR FLIGHT RESEARCH

K. BAVENDIEK (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 417-431. Copyright

For practical flight testing the Technische Universitaet Braunschweig acquired a DORNIER DO28 Skyservant as research aircraft. A general data acquisition system for the various research projects is installed in the research aircraft. It is very flexible and universal, therefore it can be used for a large number of different tasks and users. It includes a complete sensor equipment with high accuracy. A high performance computer system and a multiple redundant data storage system is incorporated in the aircraft. The design objective of the onboard data processor system is to integrate user software packages for different research projects into the data acquisition program. There is another high performance data system on ground for post flight data evaluation.

Author

#### A90-12234#

##### AN ELECTRONIC FLIGHT-RECORDER FOR A HANG-GLIDER

SHUICHI ITOH, MASAHIRO ISHII, TATSUHIKO MATSUKAWA, YASUO FUKAMACHI, and YOSHIHARU SAIKI University of Electro-Communications, Bulletin (ISSN 0915-0935), vol. 2, June 1989, p. 9-15. In Japanese, with abstract in English.

An attempt was made to determine the state of an air current in the vicinity of the flying zone of a hang glider by analyzing data obtained from an actual flight. A flight recorder to be carried on a hang glider was built and the data recorded during the flight were analyzed to evaluate the effectiveness of the recorder. The data were sent to a personal computer via magnetic recording tape and corrected to reproduce the flight route. This route was combined with data on the ascending or descending air current and the position of the updraft or downdraft. Tolerable results concerning the conditions of the air current were obtained.

C.D.

**N90-10032#** National Center for Atmospheric Research, Boulder, CO. Atmospheric Technology Div.

##### MEETING REVIEW: WORKSHOP ON AIRBORNE INSTRUMENTATION

WILLIAM A. COOPER and DARREL BAUMGARDNER Mar. 1989 83 p Presented at the Workshop on Airborne Instrumentation, Boulder, CO, 19-21 Oct. 1988 (Contract NSF ATM-87-09659) (PB89-174775; NCAR/TN-330+PROC) Avail: NTIS HC A05/MF A01 CSCL 01/4

A workshop was held at NCAR (the National Center for Atmospheric Research) to review the needs for airborne

## 07 AIRCRAFT PROPULSION AND POWER

instrumentation and to plan for the development of needed instruments. Areas covered included state parameters (pressure, temperature, wind, humidity measurement), air motion sensing, cloud physics, atmospheric electrification, remote sensing, gas-phase chemistry, aerosols, and deployable sensors in oceanography. Several measurement needs were identified and discussed. A summary of conclusions and recommendations is given. K.C.D.

### 07

## AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

### A90-10152

#### AEROSOL EFFECTS ON JET-ENGINE IR RADIATION

S. A. WEISROSE, R. DAVIDSON, M. LINDNER, S. JACOBSON, and J. WALLACE (Israel Aircraft Industries, Ltd., Lod) IN: Infrared technology XIV; Proceedings of the Meeting, San Diego, CA, Aug. 15-17, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 144-160. refs Copyright

Results are presented from simulation studies on the possibility of ejecting an aerosol cloud of carbon particles around the exhaust plume to reduce the amount of IR radiation emitted by a jet engine. The components of the experimental facility are described, including an engine simulator, a radiometric measuring apparatus, and the aerosol injection system. The cloud reduction factors determined from radiation measurements are compared with theoretical predictions. The results show that a cloud of C particles is able to attenuate the IR radiation emitted by the engine simulator. It is suggested that further operational research is needed to test the feasibility of the method. R.B.

### A90-10839

#### FUNDAMENTALS OF TURBINE DESIGN FOR AIRCRAFT ENGINES [OSNOVY PROEKTIROVANIA TURBIN AVIADVIGATELEI]

ALEKSANDR V. DEREVIANKO, VLADIMIR A. ZHURAVLEV, VLADIMIR V. ZIKEEV, V. V. KNIAZEV, S. Z. KOPELEV et al. Moscow, Izdatel'stvo Mashinostroyeniya, 1988, 328 p. In Russian. refs Copyright

The theory and gasdynamic principles of turbine design for aircraft engines are presented. In particular, recommendations are given concerning the selection of the design scheme and determination of the flow path dimensions and geometry. The effect of the structural elements of the hot flow path and of the cooling system on turbine efficiency is analyzed. Attention is also given to methods of the air cooling of blades, calculation of blade temperature, profiling of blade cascades, and strength analysis. V.L.

### A90-11008#

#### WHIRL-FLUTTER INVESTIGATION ON AN ADVANCED TURBOPROP CONFIGURATION

F. NITZSCHE (Empresa Brasileira de Aeronautica, S.A., Sao Jose dos Campos, Brazil) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2, p. 1077-1084) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 939-946. Previously cited in issue 12, p. 1831, Accession no. A88-32287. refs Copyright

### A90-11142#

#### CERAMIC HEAT EXCHANGERS IN GAS TURBINE

P. AVRAN and S. BOUDIGUES (ONERA, Chatillon-sous-Bagneux, France) ONERA, TP no. 1989-109, 1989, 9 p. refs (ONERA, TP NO. 1989-109)

This paper describes theoretical and experimental work carried out at ONERA concerning the ceramic heat exchangers and their applications in engines or gas turbines. A part of this project has been supported by DRET (Direction des Recherches, Etudes et Techniques), an agency of the Ministry of Defense of France. The interest of using ceramic materials is described, the design and the development of a barrel type recuperators are reviewed, and their application to three examples (terrestrial, aeronautical and space) are discussed. Finally the test facility is presented and the main experimental results are compared with a simple theoretical calculation. Author

### A90-11431

#### FLOW AROUND A JET AND THRUST MEASUREMENT BIAS FROM STATIC TESTS [ECOULEMENT AUTOUR D'UN PROPULSEUR ET BIAIS DE MESURE DE POUSSEE LORS D'ESSAIS STATIQUES]

J. BRISSART and J. SAUVEL AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 21 p. In French.

(AAAF PAPER NT 88-11) Copyright

Flow visualizations around jets have been performed in order to evaluate the thrust measurement bias created by the air flow induced by the jet of a solid-propellant engine on a test bench at atmospheric pressure. Results are presented for ambient pressure and parasitic effects. It is found that the negative pressure generated by this flow is negligible, but that drag forces are significant. The effects of the geometric characteristics of various test bench configurations on thrust measurements are also determined. The results are used to explain differences in specific impulse data reported by different test facilities. R.R.

### A90-11432

#### TURBULENT MIXING IN HELICOPTER JET DILUTERS - NAVIER-STOKES CALCULATIONS AND CORRELATIONS [MELANGE TURBULENT DANS LES DILUEURS DE JET POUR HELICOPTERES - CALCULS NAVIER-STOKES ET CORRELATIONS]

FRANCOIS TOULMAY (Aerospatiale, Division Helicopteres, Marignane, France), MARIELLE CANTILLON, and SERGE BOISSIERE (Aix-Marseille I, Universite, Marseille, France) AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 24 p. In French. Research supported by DRET. refs

(AAAF PAPER NT 88-13) Copyright

Time-averaged Navier-Stokes equations have been used along with a two-equation turbulence model in order to predict the performance of jet diluters. The diluters make use of the residual kinetic energy in the turboshaft's exhaust jets to suck in cool ambient air which is mixed with hot gases via an ejector. The present code uses the finite volume technique to treat plane or axisymmetric flows, and employs orthogonal curvilinear coordinates to model the wall geometry. The results are compared with previously published data. Although the method is shown to correctly predict velocity fields (particularly the position and extent of the recirculation zones), the wall pressure calculations are found to be inaccurate. R.R.

### A90-11553#

#### THE DESIGN OF ROTOR BLADES TAKING INTO ACCOUNT THE COMBINED EFFECTS OF VIBRATORY AND THERMAL LOADS

A. M. SHARAN (Newfoundland, Memorial University, Saint John's, Canada), J. S. RAO (Indian Institute of Technology, New Delhi, India), and R. BAHREE ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN 0022-0825), vol. 111, Oct. 1989, p. 610-618. refs (Contract NSERC-A-5549) Copyright

The present work involves the design of rotor blades based

on the thermal as well as centrifugal and nozzle excitation forces in the transient state. The finite element analysis has been used to calculate these stresses. The nozzle excitation forces have been modeled as a series of impulses occurring at instants of time known from the solution of kinematic equations. Author

#### A90-11554#

##### RUB INTERACTIONS OF FLEXIBLE CASING ROTOR SYSTEMS

F. K. CHOY, J. PADOVAN, and C. BATUR (Akron, University, OH) ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN 0022-0825), vol. 111, Oct. 1989, p. 652-658. refs

Copyright

A comprehensive analytical treatment is undertaken for the complex rub interaction between a rotor assembly and its casing structure, using the orthogonal coupled rotor-casing modes to obtain accurate relative motion between rotor and casing. An external base vibration input and a sudden increase in imbalance are used to simulate the sudden imposition of an adverse operating condition. The dynamic characteristics of the system are examined in both the time and frequency domains by means of a numerical FFT procedure. A multibearing, flexible casing rotor system is treated as an illustrative example of the method, and conclusions are drawn from the results of an extensive parametric study.

O.C.

#### A90-11558#

##### TURBOMACHINERY BLADE VIBRATION AND DYNAMIC STRESS MEASUREMENTS UTILIZING NONINTRUSIVE TECHNIQUES

J. R. KADAMBI, R. D. QUINN, and M. L. ADAMS (Case Western Reserve University, Cleveland, OH) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 111, Oct. 1989, p. 468-474. refs

Copyright

The feasibility of developing an in-service noninterference system for measuring/monitoring steam turbine and gas turbine jet engine blade vibrations is investigated by examining the applicability of magnetic, inductive, optical, and laser and acoustic Doppler measurement methods. It is concluded that the methods that hold the greatest promise include the laser Doppler vibration and optical sensor probes, and a combination of these. The problem of the conversion of the blade vibration measurements into meaningful blade stresses can be addressed by finite element computational techniques and model analysis. I.S.

#### A90-11562#

##### OPTIMUM TRAILING EDGE EJECTION FOR COOLED GAS TURBINE BLADES

T. SCHOEIRI (Texas A & M University, College Station) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 111, Oct. 1989, p. 510-514. refs

Copyright

The effect of trailing edge ejection on the flow downstream of a cooled gas turbine blade is investigated. Parameters that affect the mixing losses and therefore the efficiency of cooled blades are the ejection velocity ratio, the cooling mass flow ratio, the slot-width ratio, and the ejection angle. For an ejection velocity ratio of 1, the trailing edge ejection reduces the mixing losses downstream of the cooled blade. For given cooling mass flow ratios, optimum slot-width/trailing edge ratios are found, which correspond to the minimum mixing loss coefficients. Author

#### A90-11794#

##### FLUTTER OF TURBINE BLADES

D. S. WHITEHEAD IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 437-452. refs

Calculations using program FINSUP have been done on the

aeroelastic stability of turbine blades with a typical aerofoil section. The program includes the effects of camber, thickness and mean deflection of the flow, and the calculations are done for both subsonic and supersonic exit Mach numbers. Substantial regions of instability are found for accurately tuned blades with no mechanical damping. In actual blades mistuning and mechanical damping will tend to stabilize the system. The results show the important effect of some torsion in a predominately bending mode. The effect of interblade coupling through tip shrouds or lacing wires is also examined. Acoustic resonances show large effects over small ranges of interblade phase angle, but the practical importance of these is in doubt. Author

#### A90-11795#

##### IMPROVED DOUBLE LINEARIZATION METHOD FOR PREDICTION OF MEAN LOADING EFFECTS ON SUBSONIC AND SUPERSONIC CASCADE FLUTTER

M. NAMBA and K. TOSHIMITSU (Kyushu University, Fukuoka, Japan) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 453-471. refs

The paper presents an improved mathematical formulation of the double linearization theory for predicting mean loading effects on flutter of two- and three-dimensional cascades in subsonic and supersonic flows. The double linearization theory deals with both steady and unsteady components of flow disturbances on the basis of linearized approximation by assuming that the cascade is lightly loaded and vibrating with an infinitesimally small displacement amplitude. The improvement consists in taking into account the effect of equivalent unsteady mass sources due to motion of blades with steady density jump across the blade surfaces and the effect of unsteady spanwise forces due to inclination of blade surfaces and motion of streamwise steady vortices. Numerical results for unsteady aerodynamic forces show good agreement with results obtained by numerical field methods and existing experimental data. The dependence of the flutter boundaries upon various cascade design parameters are demonstrated. Author

#### A90-11796#

##### SYSTEMATIC STUDY OF FLUTTER CHARACTERISTICS OF TWO-DIMENSIONAL CASCADES IN INCOMPRESSIBLE FLOW

MR. SULARSO (Bandung Institute of Technology, Indonesia) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 473-498.

A systematic study of the aeroelastic behavior of cascades is presented to demonstrate the influence of various parameters involved. The parameters affecting the aerodynamic forces are the reduced frequency, interblade phase angle difference, and cascade geometry. The cascade geometry is determined by the profile shape of the blades, angle of attack, stagger angle, pitch to chord ratio, and the axis of rotation. Furthermore, the elastomechanic parameters to be considered are the mass ratio, natural frequencies, and structural damping. The analysis is based on the two-dimensional cascade model oscillating in bending and torsion mode in an incompressible inviscid flow. Author

#### A90-11797#

##### AIRCRAFT COMPRESSOR FLUTTER ANALYSIS

H. JOUBERT, H. QUINIOU, and G. A. GEROLYMOS (SNECMA, Paris, France) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 499-527. refs

Compressor flutter is a potential source of trouble in modern aircraft engines. Its prediction is a demanding multidisciplinary

problem requiring interacting structural and aerodynamic analysis. The purpose of this work is to present the prediction and analysis of this phenomenon by using advanced computational codes and experimental data bases. After a brief description of the computational and experimental methods used, these techniques are applied in the analysis of actual aircraft-engine compressor configurations. The influence of various operating conditions on the blading aeroelastic behavior is examined. Various possible improvements of the existing methods are suggested and assessed. Author

### A90-11798#

**FLUTTER OF CASCADE BLADES COMPOSED OF BLADES HAVING ARBITRARILY DIFFERENT NATURAL FREQUENCIES**  
HIDEO TANAKA (Tokai University, Tokyo, Japan) and ICHIRO FUJIMOTO (Tokyo University, Japan) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 547-560. refs

Cascade blades exhibit natural frequency fluctuations which suggest themselves as bases for flutter suppression. This effect may be obtained by means of a blading pattern in which blades with relatively high frequencies are placed next to blades with comparatively low frequencies; care must be taken, however, to avoid blade arrangements yielding a plot of natural frequencies that produces a damped curve, or a sawtooth pattern in which the natural frequency rises continuously, or a chevron pattern in which frequency increases and decreases moderately over a series of neighboring blades. Cascades composed of groups of blades having greater natural frequency deviations are more stable in flutter than those whose frequencies are more closely grouped. O.C.

### A90-11799#

#### **THE FLUTTER CHARACTERISTIC ANALYSIS AND OPTIMIZATION DESIGN OF MISTUNING BLADE**

TAO SONG, MEI MA, and ZHAOHONG SONG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 561-582. refs

A novel design procedure is developed for the design of stable mistuned blade systems, in which the most unstable mode shape of the mistuned blade system is chosen as the cost function of optimization. Computation results thus obtained indicate that the mistuning pattern with which the system becomes most stable will vary with changing aerodynamic conditions; all of these optimum mistuning patterns, however, share a large amount of mistuning between neighboring blades. The stability of a mistuned system cannot be guaranteed solely on the basis of interblade frequency disparities. O.C.

### A90-11800#

#### **THE EFFECTS OF THREE CENTRES OF BLADE ON FLUTTER**

CHENG SHENG ZHANG and ZHAN HONG SONG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 583-595. refs

The interactive effects on turbomachine blade flutter of the blade aerodynamic center, center of gravity, and center of torsion, are presently studied by means of the dynamic equations of the coupling between bending and torsion at the equivalent cross section. In view of the dependence of aerodynamic loads on blade-vibration displacements, they are treated as a function of blade-vibration velocities. The results obtained indicate that blades with a forward center of torsion are less stable than those with

more backward ones, and that blades with forward center of gravity position are more stable than those with a forward center of torsion. O.C.

### A90-11802#

#### **FLUTTER OF MISTUNED CASCADES WITH STRUCTURAL COUPLING**

HINNE BLOEMHOF (Asea Brown Boveri AG, Baden, Switzerland) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 663-676.

The flutter vibrations of a blade cascade are presently expressed by a matrix-equation system, on the basis of the influence-coefficient model and energy considerations. The system equations are shown to be easily solvable through insertion of a quasi-harmonic solution, which allows transformation into a well-known eigenvalue problem. The kinetic, potential, structural damping and aerodynamic excitation energies are formulated as integrals of the sum of the translatory and torsional components over the entire blade height; this allows consideration of twisted/tapered blade geometries, compound vibration mode-shapes, and complex nonsteady aerodynamic forces, as well as their integral effects on blades. O.C.

### A90-12011#

#### **THE FEATURES OF FJR 710 ENGINE**

HIROKAZU MIYATAKE and HIDEO KOBAYASHI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 65-69. In Japanese, with abstract in English. refs

The flight test of the quiet STOL research aircraft ASUKA has been carried out by the National Aerospace Laboratory. The aircraft is powered by four FJR710/600S turbofan engines installed as an upper surface-blowing propulsive lift system. The FJR710/600S high bypass ratio turbofan engine, which is designed to have 4800 kgf thrust, is the latest, slightly modified version of the FJR710/600 prototype engine developed under the National Research and Development Program of the Ministry of International Trade and Industry from 1971 to 1982. The outline of the engine development program and various engine tests, such as operation under different environments, foreign object strike tests, performance and functional tests on a flying test bed, are described. C.D.

### A90-12012#

#### **ENDURANCE TEST OF FJR 710/600S ENGINE**

HIROKAZU MIYATAKE, YOSHIMASA SAGIYA, SHIN-YA AKAMA, SHIN-ICHI SHIMIZU, and SHIN-JI YOSHIMURA Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 70-75. In Japanese, with abstract in English.

150-hour endurance test and low-cycle fatigue test (overhaul test) were conducted for an FJR 710/600S engine installed on the quiet STOL research aircraft 'ASUKA' in accordance with the Japan Civil Aviation Bureau (JCAB) Airworthiness Requirement. The flight test was carried out under operational limits based on the endurance test result. Additional endurance tests were required for improvement of operational limits and for the application of design-changed parts after the flight test had been put into practice. Simulated STOL mode operational endurance test was also conducted by using the test cycle determined by the analysis of typical flight test data and using a large quantity of bleeding air from a high pressure compressor. This paper describes the outline and the results of these endurance tests. Author

### A90-12013#

#### **START CHARACTERISTICS OF FJR 710/600S ENGINE**

YOSHIMASA SAGIYA, TOSHIKI MORIMOTO, KIYOSHI NAKAZAWA, and HIDEO KOBAYASHI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 76-82. In Japanese, with abstract in English.

In order to apply the FJR710/600S engine to the low-noise STOL aircraft ASUKA, reconfirmation of a flight envelope for the

engine restart is required in accordance with Japan Civil Aviation Bureau Airworthiness Requirements. The authors have encountered troubles caused by a shortage of stall margin since the beginning of engine development, for which a solution has been found by numerous start tests in the ground test cell. Based on these data, engine restart characteristics during the flight were assumed and good coincidence with flying test bed experimental results was obtained. The prediction method for the engine restart and the analytical results are described, and the statistical data for start failure on board are shown. C.D.

**A90-12014#****OIL MIGRATION OF FJR 710/600S ENGINE**

YOSHIMASA SAGIYA, HIROHARU ITAHARA, and HARUO GOTOH Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 83-87. In Japanese, with abstract in English.

Level-down of engine oil occurred during the course of the first flying test bed examination of the FJR 710/600S engine. In this phenomenon, called 'oil migration', the engine oil is hidden somewhere and the oil tank becomes empty; this may cause the failure of engine bearings by the lack of feeding oil. In order to find the cause of oil migration, several simulated oil system rig tests and associated engine tests were carried out. These tests revealed the cause of the oil migration, to be choking phenomena of the engine oil at the vertical and narrow oil passage facing the high-speed rotating shaft. This paper reports the process of troubleshooting the oil migration and the successful result of the second flying test bed examination. Author

**A90-12015#****STEADY STATE PERFORMANCE OF FJR 710/600S ENGINE**

YOSHIMASA SAGIYA, HISATERU KANEKO, and SHIN-JI YOSHIMURA Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 88-93. In Japanese, with abstract in English.

Many performance tests for the FJR 710/600S engine were carried out during the development of the prototype engine, including the altitude test at NGTE U.K. After the decision had been made to install the FJR 710/600 engines on the research aircraft NAL-QSTOL as the propulsor, six FJR 710/600S engines, slightly modified from the FJR 710/600 prototype engine, were manufactured. Additional performance tests were executed for the STOL complex propulsion system both for the open ground field test and on the flying test bed by utilizing the JSDF C-1 aircraft. This report describes the steady state performance, including sea level static, high altitude, and the large quantity of bleeding air from a high compressor in comparison with the design values, and also describes the deterioration of performance after an endurance test. Author

**A90-12016#****MECHANICAL RIG TEST OF FJR 710/600 ENGINE COMPONENTS**

HIRAO AONO, TOSHIHIRO KAWASHIMA, TETSUO CHIKATA, TATSUZO TOYODA, and YASUYUKI TANAKA Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 94-98. In Japanese, with abstract in English.

In order to obtain type certificates of the FJR 710/600 engine, mechanical rig tests using actual engine parts were conducted in accordance with the Japan Civil Aviation Bureau (JCAB) Airworthiness Requirements. This paper presents an outline of the JCAB Airworthiness Requirements for engine structural integrity and the various mechanical rig tests which were performed by IHI. The tests are: (1) an engine casing/mount strength test to show sufficient strength capable of withstanding the flight and ground loads for an airplane, (2) overspeed test and cycle spin tests of disks to demonstrate compliance with the strength requirement, (3) bird and ice hail strike tests to evaluate fan blade strength against foreign object impact damage which causes blade failure, (4) a containment test to confirm the design propriety of the casing which contains any debris originated from blade failure,

and (5) blade tests to obtain vibration characteristics and fatigue strength. Author

**A90-12017#****DESIGN OF CONTROL AMPLIFIER FOR FJR 710 ENGINE**

TATSUKI SATOH and YOSHIMITSU SOGA Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, March 1989, p. 99-102. In Japanese, with abstract in English.

The fuel control system for the FJR 710 engine consists of the hydromechanical main fuel control and electric limiting control which protect the engine from over-temperature and fan turbine overspeed. This limiting control uses analog electronics called the control amplifier, and when mounted on the engine fan casing, it was required to endure severe engine environments. Many endurance tests for this control amplifier under various environments were conducted in accordance with the JCAB Airworthiness Requirement to confirm sufficient reliability. And after the research flight test for STOL had been put into practice, some design changes of this control amplifier have been applied to raise reliability. In this paper, the outline of operational description, design concepts, problems experienced during the flight test of the STOL aircraft 'ASUKA', design-changes, etc., are described. Author

**A90-12474****POWER SUPPLY OF AIRCRAFT [ELEKTROSNABZHENIE LETATEL'NYKH APPARATOV]**

DAVID E. BRUSKIN and IGOR' M. SINDEEV Moscow, Izdatel'stvo Vysshiaia Shkola, 1988, 264 p. In Russian. refs Copyright

The book deals with the theoretical aspects and the general design and operation of the ac and dc power supply systems of aircraft. In particular, attention is given to batteries, power generators, static current transformers, automatic frequency control of synchronous generators, and voltage regulators of ac and dc generators. The discussion also covers the statics and dynamics of generator voltage regulation, abnormal regimes in power supply systems, automatic control of power supply systems, and the protection and reliability of aircraft power supply systems. V.L.

**A90-12501****INTERNATIONAL SYMPOSIUM ON AIR BREATHING ENGINES, 9TH, ATHENS, GREECE, SEPT. 3-8, 1989, PROCEEDINGS. VOLUMES 1 & 2**

FREDERICK S. BILLIG, ED. (Johns Hopkins University, Laurel, MD) Symposium organized by the Greek National Committee and National Technical University of Athens; Sponsored by the Greek General Secretariat for Research and Technology, Hellenic Aerospace Industry, Ltd., Hellenic Air Force, CEC, and International Society for Air Breathing Engines. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. Vol. 1, 627 p.; vol. 2, 719 p. For individual items see A90-12502 to A90-12639. Copyright

The conference presents papers on the National Aerospace Plane Program, highly loaded axial flow compressors, Swedish philosophy in aeroengine development, the active control of engine instabilities, and turbulent free shear layer mixing and combustion. Consideration is also given to direct and hybrid solutions of three-dimensional flow in axial radial turbomachines using the mean stream surface method, the numerical simulation of turbomachinery flows with a simple ONERA model of viscous effects, and the combustion characteristics of a boron-fueled SFRJ with aft burner. Other topics include studies on the influence of Mach number on profile losses of a reaction turbine cascade, flow in compressor interstage ducts, and full-scale liquid fuel ramjet combustor tests. K.K.

**A90-12502\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**ADVANCES IN COMPUTATIONAL DESIGN AND ANALYSIS OF AIRBREATHING PROPULSION SYSTEMS**

JOHN M. KLINEBERG (NASA, Lewis Research Center, Cleveland, OH) IN: International Symposium on Air Breathing Engines, 9th,



## 07 AIRCRAFT PROPULSION AND POWER

Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 3-17. Previously announced in STAR as N89-23465. refs

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The development of commercial and military aircraft depends, to a large extent, on engine manufacturers being able to achieve significant increases in propulsion capability through improved component aerodynamics, materials, and structures. The recent history of propulsion has been marked by efforts to develop computational techniques that can speed up the propulsion design process and produce superior designs. The availability of powerful supercomputers, such as the NASA Numerical Aerodynamic Simulator, and the potential for even higher performance offered by parallel computer architectures, have opened the door to the use of multi-dimensional simulations to study complex physical phenomena in propulsion systems that have previously defied analysis or experimental observation. An overview of several NASA Lewis research efforts is provided that are contributing toward the long-range goal of a numerical test-cell for the integrated, multidisciplinary design, analysis, and optimization of propulsion systems. Specific examples in Internal Computational Fluid Mechanics, Computational Structural Mechanics, Computational Materials Science, and High Performance Computing are cited and described in terms of current capabilities, technical challenges, and future research directions.

Author

### A90-12503#

#### HIGHLY LOADED AXIAL FLOW COMPRESSORS - HISTORY AND CURRENT DEVELOPMENTS

A. J. WENNERSTROM (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 21-34. refs

Approaches taken to achieve very high loading levels in axial-flow compressors are discussed with particular attention given to aircraft turbine engines. An attempt was made to reduce the size and weight of the powerplant, to increase its simplicity and ruggedness, and to reduce cost. It is shown that increased work per stage can only be obtained by increasing the Mach number, diffusion, or both. The use of through-blade design methods and three-dimensional analysis codes made it easier to deal with high Mach number designs. In fans, it is suggested that further improvements may be achieved through the use of splitters. In core compressors, greater use of counterswirl to raise Mach numbers may be the best way to increase average stage loading.

K.K.

### A90-12504#

#### SWEDISH PHILOSOPHY IN AEROENGINE DEVELOPMENT

ARNE WITTLOV (Volvo Flygmotor, AB, Trollhattan, Sweden) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 35-44.

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The development of Swedish combat aircraft jet engines is discussed. The strategic importance of domestic self-sufficiency in engine selection is demonstrated as well as adaptation to Swedish military requirements, and long-term product support. The need for supplementary technology and manufacturing development in commercial aeroengines as well as in space propulsion technology is pointed out.

K.K.

### A90-12505#

#### THE ACTIVE CONTROL OF ENGINE INSTABILITIES

J. E. FLOWCS WILLIAMS (Cambridge, University, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 45-48. refs

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Energy issues pertaining to the active control of engine instabilities are discussed. Particular attention is given to the active control of combustion instabilities, the active elimination of vortex shedding, and the elimination of surge on a centrifugal compressor. It is noted that the energy costs of these controllers are negligible.

K.K.

### A90-12508#

#### SOME ISSUES IN THE GROWTH OF SMALL GAS TURBINE AIRCRAFT PROPULSION ENGINES

MONTGOMERIE C. STEELE (Allied-Signal Aerospace Co., Garrett Engine Div., Phoenix, AZ) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 80-89.

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Progress made in the development of aircraft propulsion gas turbine engines is described. A typical TPE331 series engine having a single shaft encompassing a two-stage centrifugal compressor, a reverse-flow annular combustor, and a three-stage axial turbine is described. Turbofan engines are described with attention given to bird ingestion, fan gear train, and a mixer compound thrust nozzle.

K.K.

### A90-12516#

#### SIMULATION AND SECOND LAW ANALYSIS OF THE UNSTEADY COMBUSTION OF A NON-IDEAL PULSATING RAMJET

I. SINAN AKMANDOR and A. YALCIN GOGUS (Middle East Technical University, Ankara, Turkey) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 155-170. refs

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The unsteady periodical H<sub>2</sub>-air combustion within a pulsating ramjet has been analyzed using the method of characteristics. The reaction has been shown to be much faster when compared to the convective transport. Thus, the flow within the chamber has been solved, revealing the combustion pressure waves sweeping the quasi-one-dimensional engine core. Friction and heat transfer from the reaction to the fluid have been taken into account by retaining relevant source terms in the compatibility equations. A marching algorithm obeying the CFL criteria is used to solve the following primitive variables: velocity, pressure and density. Thrust and specific fuel consumption have been determined. Based on these flow properties, the time variation of the entropy generation due to friction and combustion have been calculated. The energy balance across the pulsating and steady ramjets have also been determined.

Author

### A90-12528#

#### FULL-SCALE LIQUID FUEL RAMJET COMBUSTOR TESTS

BJORN SJOBLUM (Volvo Flygmotor, AB, Trollhattan, Sweden) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 273-281. Research supported by the Forsvarets Materielverk. refs

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This paper considers a full-scale combustor which is based on experience from the smaller predecessors. Much of the work was concentrated on fuel injector modifications to achieve adequate combustion performance. High-altitude-test data for the two best injector configurations are presented, including stability limits, combustion efficiency, and pressure oscillations. A specific problem, due to the influence of combustor inlet temperature on fuel distribution, is commented upon. Furthermore, the validity of the theta-parameter is discussed.

Author

### A90-12529#

#### HYDROGEN FUELED SUBSONIC-RAM-COMBUSTOR MODEL TESTS FOR AN AIR-TURBO-RAM ENGINE

T. TAMARU, K. SHIMODAIRA, T. SAITO, H. YAMADA, and S.



HORIUCHI (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 282-290. refs  
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This paper deals with a basic study to facilitate the design for the hydrogen fueled subsonic ram combustor. Three types of the flame holder scaled 1/10 of an estimated actual size were investigated to evaluate the performance for the severe inlet conditions of the hypersonic flight. Unidimensional analysis with total pressure at the exit and the static pressure on the duct wall gave the gas temperature and the Mach number of the combustion gas. Analysis of sampled gas at the exit gave radial profiles of equivalence ratio, combustion efficiency and so on. These results indicate that fuel rich zone over stoichiometry must be avoided for the fuel preparation to attain the best combustion efficiencies near stoichiometric mixture condition which is required for the engine for hypersonic flight. Author

**A90-12530#**  
**EXPERIMENTAL STUDY OF STATIC PRESSURE AND MEAN VELOCITY PROFILES INSIDE A TWO-DIMENSIONAL DUMP-TYPE COMBUSTOR MODEL**

B. H. L. GOWDA, S. SRINIVASAN, and R. NATARAJAN (Indian Institute of Technology, Madras, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 291-295. refs  
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In order to facilitate the understanding of the complex flow fields inside a dump-type combustion chamber commonly employed in ramjets, the present investigation employs a two-dimensional model, to study the effect of variation of the dump angle on the static-pressure and mean-velocity fields inside the model. The experiments were carried out for three dump angles, viz, 0, 30, and 60 deg. The approach Reynolds number, referred to the inlet width, was kept constant at 100,000 (corresponding to an inlet velocity 31 m/s). It is found that the dump angle has a significant effect on the extent of the central recirculation zone, the position of the confluence point, the reattachment length, and the distance required for complete mixing. The mixing is quite rapid at large values of dump angle; at smaller angles, much larger lengths are required for mixing. Author

**A90-12532#**  
**A STUDY OF TWO-PHASE FLOW FOR A RAMJET COMBUSTOR**

D. LAREDO, Y. LEVY, and Y. M. TIMNAT (Technion - Israel Institute of Technology, Haifa) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 305-324. refs  
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The two-phase flow in a ramjet combustor is studied theoretically and experimentally. An attempt is made to improve the classical model applied to dump combustors by introducing experimental measurements of the initial conditions for the fuel spray at the inlet plane of the combustor. The flow geometry chosen was an axisymmetric sudden expansion. The parameters studied were the droplet initial conditions, the chemical reaction rates, and the temperature boundary conditions. K.K.

**A90-12540#**  
**DESIGN AND OFF-DESIGN PERFORMANCE PREDICTIONS OF AXIAL TURBINES**

R. K. SULLEREY and J. PANDYA MAHAGNA (Indian Institute of Technology, Kanpur, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 391-396. refs  
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Present investigations deal with performance predictions of axial

flow turbines at design point and off-design operating conditions. Analysis has been carried out for single and multistage turbines using streamline curvature method with one of the most appropriate design point loss correlations. Incidence losses and deviation arising out of incidence and Mach number effects have been accounted for in the analysis at off-design mass flow rates. Secondary losses have been distributed across the annulus with concentration toward hub and tip regions in a manner that is commensurate with test results. The results of the analysis have been compared with experimental measurements. Author

**A90-12546#**  
**INVESTIGATION AND IMPROVEMENT OF GROUND STARTING CHARACTERISTICS OF A COMBUSTOR WITH AIRBLAST NOZZLES**

QINGGUO LIU (Shenyang Aeroengine Research Institute, People's Republic of China) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 449-454. refs  
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The test investigation results of the combustion characteristics at the ground starting conditions are presented. The results indicate that the poor fuel atomization quality, caused by low air velocity through airblast nozzles, led to poor combustion characteristics, such as narrow range of starting ignition, low combustion efficiency, long flame, nonuniform outlet temperature distribution, and pulse combustion with noise at the ground starting conditions. The results also showed that the above defects could be overcome and the combustion characteristics could be improved by introducing some auxiliary air through nozzles for improving fuel atomization. A new airblast nozzle version is presented which can be used in the future airblast nozzle design. Author

**A90-12547#**  
**CONTROLLED MIXING AND VARIABLE GEOMETRY COMBUSTOR DESIGN EFFECTS ON EMISSIONS AND COMBUSTION CHARACTERISTICS**

A. K. GUPTA, J. CHOMIAK (Maryland, University, College Park), N. MARCHIONNA (Textron Lycoming, Stratford, CT), and M. S. RAMAVAJJALA IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 455-464. Research supported by Textron Lycoming. refs  
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Earlier studies carried out on swirl flows, both experimental and theoretical, show a significant effect of burner geometry, swirl strength and fuel injector geometry on mixing, combustion processes and emission of trace pollutants. The variable geometry swirl combustor in the form of a multiannular swirl burner arrangement, used at the University of Maryland, consists of six concentric annuli arranged telescopically. The fuel is introduced nominally in the center annulus and the air through the outer annuli. This paper compares this type of burner with a new configuration in which premixed fuel and air mixture is introduced near the center. The main advantage of this new design is that the centrifugal forces developed by the swirl move the lighter, high temperature burnt gases toward the center of the combustor and the heavier, secondary and dilution air which is introduced near the center, toward the wall. This results in much better mixing, good pattern factor, high combustion efficiency, low emission levels and low burner pressure losses. Author

**A90-12548#**  
**THE PERFORMANCE OF A SMALL COMBUSTOR OPERATED OVER A WIDE RANGE OF CONDITIONS**

J. ODGERS, D. KRETSCHMER, F. RHEAUME (Universite Laval, Quebec, Canada), G. PEARCE, and N. REPACHOLI (Defence Science and Technology Organisation, Aeronautical Research Laboratories, Melbourne, Australia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989,

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Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 465-470. refs  
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For a small downstream injection combustor, using a single paraffinic fuel, numerous data have been obtained for exhaust hydrocarbons, weak extinctions and wall temperatures, measured over a wide range of inlet temperatures, pressures, combustor Mach numbers and equivalence ratios. To study separately the influence of droplet size, many of the experimental conditions have been repeated using three different fuel atomizers having the same cone angle. Correlations are presented for the exhaust pollutants (CO & HC), combustion efficiency and weak extinctions. Wall temperatures are more lightly treated. The results show rather unexpected conclusions with respect to the effects of droplet size on the results examined. Author

### A90-12552#

#### APPLICATION OF THREE-DIMENSIONAL METHODS FOR THE CALCULATION OF GAS DYNAMIC AND THERMAL PROCESSES AT THE DESIGN OF GAS TURBINES FOR AIR BREATHING ENGINES

M. I. A. IVANOV and V. K. KOSTEGE (Tsentr'nyi Nauchno-Issledovatel'skii Institut Aviatsionnogo Motorostroeniia, Moscow, USSR) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 497-505. refs  
Copyright

This paper is concerned with numerical simulation of three-dimensional gas dynamics and thermal problems of turbine design. The investigation of turbine aerodynamic cleanness is based on the numerical solution of the Euler and Navier-Stokes equations. Here, the implicit high-order-accuracy difference methods are used. The calculation of thermal processes is fulfilled with the help of the finite-element method. The joint solution of these problems makes it possible to have the correct boundary conditions on turbine element surfaces. The application of the developed computational methods permits the local and integral characteristics of cooled turbines to be obtained at the design stage. Author

### A90-12559#

#### EXPERIMENTAL STUDY ON AUTOIGNITION IN A SCRAMJET COMBUSTOR

YUKINORI SATO, MASAMI SAYAMA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), GORO MASUYA, TOMOYUKI KOMURO, KENJI KUDOU (National Aerospace Laboratory, Kakuda, Japan) et al. IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 569-576. refs  
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The characteristics of the autoignition of hydrogen fuel injected transversely to the air flow in a scramjet combustor were investigated using the scramjet combustor model described by Komuro et al. (1988). Special consideration was given to the effects produced by different fuel injection patterns, i.e., from orifices on both walls, from orifices on a single wall, and from a single orifice; for these patterns, autoignition limit curves relating the fuel equivalence ratio to total stream temperature were obtained. Compared with injection from a single orifice, injection from multiple orifices was found to enhance autoignition appreciably. The curves obtained for runs for a single orifice fuel injection agreed well with the theoretical model of Huber et al. (1979). However, for injection from multiple orifices, either on one or both walls, the agreement was poor, due to the effect of jets from adjacent and opposite wall orifices. I.S.

### A90-12560\*# Queensland Univ., Brisbane (Australia).

#### HYPERSONIC COMBUSTION OF HYDROGEN IN A SHOCK TUNNEL

R. G. MORGAN and R. J. STALKER (Queensland, University, Brisbane, Australia) IN: International Symposium on Air Breathing

Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 577-584. Research sponsored by NASA and Australian Research Grants Scheme.  
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Results are reported on shock-tunnel experiments testing the feasibility of hypersonic combustion and thrust generation in a hydrogen scramjet model. Tests with a constant-area duct show that hypersonic combustion is possible with a central injection at static intake pressures of about 20 kPa. The results of a comparison made between model configurations with nominal combustion-chamber intake Mach numbers of 4 and 6 indicated that the hypersonic duct gives a better performance at flight enthalpies above 7 MJ/kg. It is argued that the lower temperatures associated with hypersonic flow produce more efficient combustion. I.S.

### A90-12562#

#### THE USE OF PULSE FACILITIES FOR TESTING SUPERSONIC COMBUSTION RAMJET (SCRAMJET) COMBUSTORS IN SIMULATED HYPERSONIC FLIGHT CONDITIONS

R. C. ORTH and J. I. ERDOS (General Applied Science Laboratories, Inc., Ronkonkoma, NY) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 596-604. refs  
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The requirements of pulse facilities (such as a reflected shock tunnel or an expansion tunnel) for testing hypersonic scramjet combustors are examined. These facilities, in addition to enabling ground testing of hypersonic scramjet combustor components with relatively inexpensive facilities and models, feature low heat loads to both the facility and the combustor models, the advantage of instrument survivability, and very accurate heat-transfer measurements and good cold-wall simulation with models at room temperature. Results from a scramjet combustor test program designed to address the requirements of a pulse facility are presented. Tests results demonstrated a scramjet combustion simulation at flight speeds in the Mach number range 9-10. Tests are planned for an expansion tunnel facility, which will extend the ground test scramjet simulation range to Mach 15-18. I.S.

### A90-12564#

#### STRESS ANALYSIS OF GAS TURBINE BLADED DISC FOR STRUCTURAL INTEGRITY APPLYING THE CONCEPT OF CYCLIC SYMMETRY

SMT. ANURADHAKUMAAR (Gas Turbine Research Establishment, Bangalore, India) and V. RAMAMURTI (Indian Institute of Technology, Madras, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 616-623. refs  
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Using finite element discretization technique, a numerical procedure is developed for the static stress analysis of gas turbine bladed disks. In this method, the component of the bladed disk is divided into as many substructures as there are blades, and each sector is divided into a triangular mesh assuming plate elements subjected to both in-plane and bending loads. For the evaluation of displacement vectors, the Cholesky approach with variable band width is applied using appropriate boundary conditions. The procedure was validated against the exact theoretical solutions. Analyses of several different bladed disk assemblies are presented to illustrate the program. I.S.

### A90-12568#

#### AIRCRAFT ENGINE VIBRATION ANALYSIS

BRIAN REBBECHI (Defence Science Technology Organisation, Aeronautical Research Laboratories, Melbourne, Australia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p.

652-658. refs

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All aircraft engines exhibit vibration to some extent. This paper looks at methods of measurement and problems that can occur. Examples of vibration analysis of several gas turbine engines are given. The results of phase measurement are presented, and show the influence of what is thought to be thermal distortion, on unbalance. The dynamic interaction between a rotor and its supports is discussed in the context of an aircraft engine, and the results of a theoretical and experimental analysis of the interaction between rotor unbalance distribution and support characteristics is presented. These results demonstrate why there is not a linear relationship between vibration levels in one support and that in another (e.g. between test stand and aircraft). The ways in which it is possible to isolate faults to a particular module in an engine are discussed, and results are given of a theoretical and experimental study where unbalance magnitude, phase, and position were successfully predicted. Author

**A90-12569#****PRESSURE SURFACE TRAILING EDGE SLOT COOLING**

B. CAREL, A. E. BOURGUIGNON (SNECMA, Moissy Cramayel, France), Y. SERVOUZE (ONERA, Chatillon-sous-Bagneux, France), D. CUNAT, and R. RODELLAR (Turbomeca, Bizanos, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 661-668. refs

(ONERA, TP NO. 1989-123) Copyright

This paper describes a test rig designed to acquire data required for the development of calculation methods for turbine vane trailing edges cooled by pressure side slots. The experimental apparatus, the instruments used, and the working conditions required in the test are described. The effects of the inner and outer parameters of the rig (such as the blowing rate and Mach number) on the distribution of the film cooling effectiveness locally measured in the slots are analyzed. The first tests which were conducted verified the aerodynamic behavior of the cascade and provided information on the film effectiveness. I.S.

**A90-12570#****TEMPERATURE SCALING OF TURBINE BLADE HEAT TRANSFER WITH AND WITHOUT SHOCK WAVE PASSING**

M. J. RIGBY (Rolls-Royce, PLC, Derby, England), A. B. JOHNSON (Schlumberger Cambridge Research, England), M. L. G. OLDFIELD, and T. V. JONES (Oxford, University, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 669-679. Research supported by Rolls-Royce, PLC. refs

(Contract F33615-84-C-2475)

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This paper presents a scaling model for the prediction of heat transfer in a film-cooled turbine blade, with and without a simulated shock-wave passing, together with experimental results supporting the model. It is shown that, without shock-wave passing, a reduction of the heat transfer rate measurements (in terms of a Nusselt number) based simply on the local temperatures shows a scatter which masks the film cooling effects, which can be removed by considering the recovery temperatures and the effect of gas-to-wall temperature ratio, and by compensating for variations in the upstream wall temperatures and normalizing data with respect to a gauge upstream of the film cooling row. With a strong shock wave passing, however, the reflected shock waves cause an enhancement of the early suction surface heat transfer rates, which does not collapse with the temperature scaling used for the steady flow measurements. This theory can be used to predict the shock-wave-passing effects on the turbine-blade heat-transfer rates at different gas-to-wall temperature ratios. I.S.

**A90-12571#****COOLING CHARACTERISTICS OF A RADIAL WAFER BLADE**

TAKAO KUMAGAI, TOYOAKI YOSHIDA (National Aerospace

Laboratory, Chofu, Japan), and MASAKATSU MATSUKI (Nippon Institute of Technology, Minami, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 680-686. Sponsorship: Research supported by the Agency of Industrial Science and Technology. refs

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A full coverage film cooled rotor blade model was developed as an advanced type for gas turbine blades. The model was made with laminated stainless wafers. Chemical etching and diffusion bonding were applied for its fabrication. The subsequent main objective was to attain high cooling effectiveness with a single passing of coolant through a stepwise cooling passage. Experimental works are composed of a water discharge test, an airflow discharge test and a high temperature cascade test. Cooling effectiveness obtained in the present study was compared with those from various air-cooled turbine vanes/blades developed in the Advanced Gas Turbine Japan national project. The blade model was successfully made in the fourth stage of trial fabrication. As a representative result, mean cooling efficiency is slightly above 0.5 with a coolant mass flow rate of 3 percent. Author

**A90-12572#****AN EXPERIMENTAL INVESTIGATION OF ISOTHERMAL SWIRLING FLOW IN A MODEL OF A DUMP COMBUSTOR**

S. A. AHMED, R. S. BORAY, and A. S. NEJAD (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 689-702. Research supported by USAF. refs

An experimental investigation of isothermal swirling flow was conducted in a model of a coaxial dump combustor. A free vortex type swirler was designed and fabricated to impart swirl to the flow. A two component LDV system was used to obtain measurements of the three dimensional flowfield. Detailed data base is provided to facilitate development of turbulence closure models capable of accurate prediction of swirling recirculating flows. The results showed that swirl significantly modified the characteristics of the combustor flowfield and greatly enhanced turbulent mixing. Author

**A90-12573#****EFFECT OF PRIMARY AIR SWIRL ON EMISSIONS FORMATIONS IN GAS TURBINE COMBUSTORS**

A. A. DESOKY and S. H. EL-EMAM (Mansoura University, Egypt) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 703-711. refs

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The effect of primary air swirl on emissions formations in a gas turbine combustor was investigated using a specially designed apparatus, in which measurements of temperature distributions and the CO concentrations, unburned hydrocarbons, and NO<sub>2</sub> were carried out for various primary air swirl numbers and primary air/fuel ratios. The results show that the strength of the primary air swirl has an important role in the mixing process and the formation of emission in gas turbine combustors. As the strength of the primary air swirl is increased, the CO concentration at the primary zone of the combustor decreases more rapidly; the NO<sub>2</sub> concentration in the upstream region of the combustor is lower with primary air swirl than without the swirl. A theoretical model was adopted to predict the rates of CO and NO<sub>2</sub> formations in a typical gas turbine combustor. Based on the theoretical results, the formation of the NO<sub>2</sub> is found to be governed by the combination of local temperature and equivalence ratio. I.S.

**A90-12574#****ON THE WEAK EXTINCTION OF GAS TURBINE COMBUSTORS**

D. KRETSCHMER and J. ODGERS (Universite Laval, Quebec,

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Canada) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 712-720. refs  
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The weak limits of a number of combustion systems are considered, ranging from simple laminar flames through well-stirred reactors to gas turbine combustors having pressure-jet or air-blast fuel injection. Operating conditions have varying inlet conditions ( $T_3 = 250$  to  $600$  K,  $p_3 = 0.2$  to  $9.0$  atm); fuel temperature variations are also taken into account. About 80 different fuels are considered (aromatic content 0 to 100 percent, hydrogen 7.8 to 16.45 percent by mass). All of the data appear to correlate against an air-loading parameter of the type  $m(a)Vp(n)$ , with a correction for inlet temperature. The value of  $n$  is shown to be significant and to depend upon the primary zone equivalence ratio. The liquid fuels also require the evaporative effects to be taken into account. Contrary to most other workers, the correlation analysis in this work shows no dependence upon the fuel droplet size at weak extinction. Reasons are given for this. One result of the present analysis is that the correlation parameter is of a much simpler form than previously stated, but this is achieved without any loss in correlation/prediction accuracy. Author

### A90-12577# EXHAUST NOZZLE SYSTEM DESIGN CONSIDERATIONS FOR TURBORAMJET PROPULSION SYSTEMS

D. J. DUSA (GE Aircraft Engines, Cincinnati, OH) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 738-746.  
Copyright

With the advancements in aircraft gas turbine engine technology over the past decade (in materials, structures, and analytical design methods) along with those anticipated for the next decade, there is renewed interest in the Mach 3.0 to 6.0 operating regime for both commercial transports and military weapon systems. The propulsion systems for these aircraft will in all probability be a function of the flight regime selected for a particular application, i.e., a turbofan engine for Mach less than 4.0 and a dual mode turbooramjet for the Mach 4.0 to 6.0 aircraft. There are a number of component technologies that will have to be developed for the propulsion system before these applications can become a reality. This paper addresses some of the tasks that will have to be accomplished relative to one of those components, the exhaust nozzle system. Author

### A90-12581# SIMULATION RESEARCH ON THE AFTERBURNING DYNAMIC CHARACTERISTICS OF ENGINE CONTROL SYSTEM

KE-JIU MAO and XU WANG (Beijing University of Aeronautics and Astronautics, People's Republic of China) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 774-781.  
Copyright

Static and dynamic mathematical models for a new type of engine and its actual hydraulic control system are proposed. A nonlinear mathematical model is used for the engine and afterburner fuel control system. With programs formed on the basis of these models, the static and dynamic close loop characteristics of this engine control system under afterburning condition has been analyzed in detail. Satisfactory results and valuable conclusions have been obtained. The results are useful for solving many practical problems of the engine control system. Author

### A90-12583# A STUDY OF PARTICLE TRAJECTORIES IN A GAS TURBINE INTAKE

S. C. TAN, D. L. MANN, R. L. ELDER, and R. I. THORN (Cranfield Institute of Technology, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of

Aeronautics and Astronautics, 1989, p. 793-800. Research supported by Rolls-Royce, PLC and Ministry of Defence. refs  
Copyright

An experimental and theoretical study of dust migration in a helicopter intake with an inertial particle separator has been undertaken. The dust particle sizes range from 15.0 to 150.0 microns screened to a fine tolerance. The dust material used included both irregular quartz and spherical ballotini particles. A prediction model was developed to simulate particle trajectories in a three dimensional axisymmetric intake which is based on the assumption that drag force is the only force of interaction between a spherical particle and the flow. Good agreement was found between measured and predicted results. Author

### A90-12584# A THEORETICAL APPROACH TO PARTICLE SEPARATOR DESIGN

D. L. MANN (Rolls-Royce, PLC, Leavesden, England) and S. C. TAN (Cranfield Institute of Technology, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 801-806. refs  
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This paper describes work carried out to develop a unified inertial particle separator design system based around computational methods. Important design criteria such as pressure loss and inlet distortion characteristics are able to be accounted for, for the first time, by the incorporation of a Navier-Stokes flow solver into the core of the design suite. Experimentation performed to validate the flow code is described and shown to fully justify the use of such a flow prediction technique. A tie up between the predicted flow field and a particle trajectory calculating program is also shown to be successful. Author

A90-12585\*# George Washington Univ., Washington, DC.

### ROTATING PRIMARY FLOW INDUCTION USING JET-FLAPPED BLADES

STEPHANE J. CORDIER (George Washington University, Washington, DC) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 807-814. refs  
(Contract DOT-MA91-85-C-50114; NAG3-860)  
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A new concept in ejector design is examined using primary jets exiting from a free spinning bladed rotor. This concept stems from a continuing effort in the development of Rotary-Jet thrust augmentors at George Washington University (GWU). An analysis of a Rotary-Jet rotor with jet-flapped blades is presented, identifying design trends beneficial to its performance. An experimental investigation was conducted to demonstrate the potential of this new concept. Several combinations of blade and shroud geometries were designed, fabricated and tested. The results are presented and discussed. Despite crudeness of fabrication, the maximum thrust augmentations obtained ranged from 1.55 to 2.14. These results demonstrate that this device is superior to all ejector designs tested with similar conventional passive diffusing shrouds. Author

### A90-12588# CALCULATION OF UNSTEADY BOUNDARY LAYER DEVELOPMENT ON AXIAL-FLOW TURBOMACHINERY BLADING

R. L. EVANS (British Columbia, University, Vancouver, Canada) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 837-846. refs  
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The boundary layers developing on turbomachinery blading are highly unsteady due to the passage of wakes from upstream blades over downstream blade rows. Under these conditions the boundary layer develops under a fluctuating freestream which exhibits a

traveling wave type of behavior. A calculation procedure capable of predicting unsteady laminar and turbulent boundary layers subject to both standing wave and traveling wave freestream fluctuations is presented. Comparison of calculations with the limited experimental data available for unsteady boundary layers shows good agreement for laminar boundary layers at low reduced frequency and reasonable prediction of the wall phase lag for turbulent boundary layers. Prediction of the velocity fluctuation amplitude is less successful, although the correct trend of the experimental data is predicted. Author

#### A90-12589#

##### A QUASI-3D DESIGN METHOD OF TRANSONIC COMPRESSOR BLADE WITH THE FUNCTION OF IMPROVING VELOCITY DISTRIBUTION

ZHENGMING WANG, HONGJI CHEN, and XIAOLU ZHAO (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 847-853. refs Copyright

Based on a series of new algorithms of three-dimensional flow in turbomachines, a quasi-three-dimensional design method of transonic compressor blade with the function of improving velocity distribution has been studied. With the help of the combination of S2 inverse problem code, S2 nonblade passage inverse code, the code of generating profile on conic surface with geometric method and S1 transonic codes of solving respectively direct, inverse and mixed problems, a more reasonable design procedure is presented. The method has been successfully applied to improving the design of an axial compressor rotor. Author

#### A90-12591#

##### THREE DIMENSIONAL NUMERICAL SIMULATION FOR AN AIRCRAFT ENGINE TYPE COMBUSTION CHAMBER

FABIENNE PIT, FRANCIS DUPOIRIEUX, HELENE TICHITSKY, and FRANCOIS LACAS (ONERA, Chatillon-sous-Bagneux, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 864-869. (ONERA, TP NO. 1989-120) Copyright

This paper describes a new code developed at ONERA. This code will compute three-dimensional unsteady turbulent reactive flows. A finite volume method with a particular definition for volume and surfaces is used. Different boundary conditions are possible. The spatial scheme contains some parameters which are varying according to the local conditions of the flow. The first results obtained by the code are displayed. They concern a three-dimensional configuration close to an industrial configuration. Author

#### A90-12593#

##### TWO-STAGE TWO-SPOOL EXPERIMENTAL CENTRIFUGAL COMPRESSOR INVESTIGATION

V. VANEK and J. NERUDA (Vyzkumny a Zkusebni Letecký Ústav, Prague, Czechoslovakia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 881-887. Copyright

The present experimental investigation of the mutual influence of the stages of a two-spool (high and low pressure) centrifugal compressor has been conducted in a specially designed facility which allowed determinations to be made of 'space-shape' performance maps. The low pressure spool's performance parameter maps are found to change minimally in all operational regions tested, while those of the high-pressure spool indicated a considerable decline. The low pressure spool's stability region was enhanced by 30 percent. O.C.

#### A90-12594#

##### INVESTIGATION OF SOME EFFECTS ON THE COMPRESSOR CHARACTERISTICS OF AN ADVANCED BLEED AIR COMPRESSOR DESIGN

GERNOT EISENLOHR (KHD Luftfahrttechnik GmbH, Oberursel, Federal Republic of Germany) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 888-894. Copyright

The effects of inlet guide vanes, compressor inlet duct air mass and bleed-air/cycle-air mass flow characteristics on the performance of an advanced bleed-air compressor for auxiliary power unit applications are experimentally investigated. Attention is given to test rig design and sensor instrumentation. All effects of components or operating conditions on the compressor, and the conclusions drawn, have been arrived at by systematically relating global values. Extensive performance trend graphs are presented. O.C.

#### A90-12607#

##### ADVANCED AIRBREATHING POWERPLANT FOR HYPERSONIC VEHICLES

F. A. HEWITT (Rolls-Royce, PLC, Bristol, England) and B. D. WARD (Rolls-Royce, Inc., Atlanta, GA) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1009-1017. Copyright

There is a wide range of airbreathing propulsion systems with potential application to high Mach propulsion for both cruise and acceleration vehicles. This paper examines some of the general issues arising in propulsion to beyond Mach 5, and some of the particular characteristics of turboramjets, turbo-rockets, pre-cooled cycles and supersonic combustion systems. The effects of designing for either an acceleration or a cruise mission are also considered. Author

#### A90-12608#

##### A STUDY ON THE PERFORMANCE OF THE TURBO-RAMJET ENGINES AT HIGH SPEED FLIGHT

HISAO FUTAMURA (Kawasaki Heavy Industries, Ltd., Jet Engine Div., Akashi, Japan), MITSUO MORITA, and HIROYUKI NOUSE (National Aerospace Laboratory, Tokyo, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1018-1025. refs

Copyright

This paper describes turbo-ramjet engine performance in high-speed flight by off-design performance calculation for application to single-stage-to-orbit vehicles and the super hypersonic transport. Two typical axial-flow turbojet engines with different pressure ratios were compared and integrated with a ramjet. The real-gas effect and chemical equilibrium effect were considered in the calculation. The result shows the estimated engine performance. Author

#### A90-12609#

##### AERODYNAMIC AND PROPULSIVE PERFORMANCE OF HYPERSONIC DETONATION WAVE RAMJETS

J. P. SISLIAN and T. M. ATAMANCHUK (Toronto, University, Downsview, Canada) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1026-1035. refs

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The present consideration of shock-induced detonation wave combustion as a basis for hypersonic propulsion employs a first-order Godunov scheme to determine the supersonic flow-field of a vehicle employing such a powerplant; the tracking of shocks and slipstreams by this means allows the generation of a configuration geometry for the design conditions. Two basic

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configurations involving multiple external or internal powerplant inlet compression-shock regimes have been studied, and attention has been given to the performance of a planar multiple external shock compression vehicle with lifting/propulsive body aerodynamic characteristics. O.C.

### A90-12611#

#### **INVERSE CYCLE ENGINE FOR HYPERSONIC AIR-BREATHING PROPULSION**

Y. RIBAUD (ONERA, Chatillon-sous-Bagneux, France) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1044-1050. refs

(ONERA, TP NO. 1989-121) Copyright

An old engine concept for high-speed air-breathing propulsion was improved on and then studied. The basic justification of this solution is the high potential integrity of the engine components to the very hot environment. After simplified and then accurate verifications, the conclusion is that this modified concept gives very interesting thermo-propulsive performances. Author

### A90-12615#

#### **OPERATING ASPECTS OF COUNTER-ROTATING PROPFAN AND PLANETARY-DIFFERENTIAL GEAR COUPLING**

M. LECHT (DLR, Institut fuer Antriebstechnik, Cologne, Federal Republic of Germany) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1078-1088. Copyright

At least in the medium performance range counter-rotating propfans are to be driven by in-line planetary gears. If the gear is designed as a planetary-differential gear the equilibrium of power split according to the gear's balance of torque must be considered. Therefore, the propfan rotor power split must be adapted to the gear performance characteristics either by design or by adequate rotor blade setting control. This paper presents an analysis of the operating behavior of counter-rotating propfans combined with planetary-differential gears for an actual flight path from take off to cruise conditions, using different scenarios of operating the propfan in line with the gear. Author

### A90-12616#

#### **GEARLESS CRISP - THE LOGICAL STEP TO ECONOMIC ENGINES FOR HIGH TRUST**

H. A. GEIDEL and D. ECKARDT (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1089-1098. Copyright

The paper discusses the new generation of advanced ducted engines (ADE), which in terms of performance characteristics rank between turbofans and open propfans. The potential of the ADEs to improve overall aircraft economics relative to today's turbofans in terms of direct operating cost reduction is demonstrated on a comparative basis. Recent study results for ADEs are described, and it is concluded that the combination of low specific fuel consumption and simple design such as the gearless crisp concept are most attractive in view of economic improvements for a wide range of thrust classes and mission lengths. C.E.

### A90-12627#

#### **RESTART CHARACTERISTICS OF TURBOFAN ENGINES**

MITSUO MORITA, MAKOTO SASAKI (National Aerospace Laboratory, Tokyo, Japan), and TADAO TORISAKI (Nihon University, Tokyo, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1200-1206. refs

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The working process of turbofan engines in starting operation was analyzed using experimental data with the FJR710 engine. A simple and practical method for calculating inflight restart characteristics was derived. It is based on the experimental data which can be obtained by engine start tests and gets rid of detailed component characteristic maps in such a low speed range as starting. The method was applied to the prediction of inflight restart limits of the FJR710 engine not only in windmilling but also in starter-assist conditions. The agreement between the predictions and the experimental results was generally good. Author

### A90-12632#

#### **ENGINE DIAGNOSTICS - AN APPLICATION FOR EXPERT SYSTEM CONCEPTS**

D. A. FRITH (Defence Science and Technology Organisation, Aeronautical Research Laboratories, Melbourne, Australia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1235-1243. Research supported by the Royal Australian Air Force. refs

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The application of knowledge engineering to diagnosis in aircraft gas turbine engines is described. The intention is to provide machine-based, expert advice to the maintenance personnel that has the capability to improve with operational use. The capabilities that are required of the expert system shell to meet these specifications are discussed, together with those factors that are special to this type of application. Author

### A90-12633#

#### **JET ENGINE FAULT DETECTION WITH DIFFERENTIAL GAS PATH ANALYSIS AT DISCRETE OPERATING POINTS**

A. STAMATIS, K. MATHIOUDAKIS, K. PAPAILIOU (Athens, National Technical University, Greece), and G. BERIOS IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1244-1250. refs

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A common feature of all differential gas path analysis methods is the necessity of measuring a number of performance variables greater or at least equal to the number of diagnostic parameters which have to be estimated. Discrete operating conditions gas path analysis (DOCGPA) is an extended version of the conventional GPA algorithms, providing the capability to overcome this problem. The present paper describes how this method can be coupled with an engine computer model in order to perform component-directed fault diagnosis. Application to a commercial turbofan engine demonstrates the effectiveness of the proposed method. Author

### A90-12638#

#### **APPLICATION OF THE DOUBLE LINEARIZATION THEORY TO THREE-DIMENSIONAL SUBSONIC AND SUPERSONIC CASCADE FLUTTER**

KAZUHIKO TOSHIMITSU and MASANOBU NAMBA (Kyushu University, Fukuoka, Japan) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1290-1298. refs

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The mathematical formulation of the improved double linearization theory to predict the effects of spanwise-nonuniform mean loading on flutter of three-dimensional cascades in subsonic and supersonic flows is presented. Two kinds of unsteady spanwise aerodynamic forces are taken into account: the aerodynamic force which is proportional to blade inclination times steady pressure difference between upper and lower blade surfaces, and the aerodynamic force which acts on the streamwise component of steady vortices moving with blades relatively to the undisturbed fluid. Numerical results are given to demonstrate the effects of



the spanwise-nonuniform angle of attack, camber, and thickness on unsteady aerodynamic responses. C.E.

#### A90-13220

##### A DISCRETE DYNAMIC MODEL OF THE CRANKSHAFT-AIRSCREW ASSEMBLY OF AN AIRCRAFT PISTON ENGINE FOR THE PURPOSE OF VIBRATION ANALYSIS BY THE METHOD OF FINITE ELEMENTS

W. SOBIERAJ (Wojskowa Akademia Techniczna, Warsaw, Poland) Journal of Technical Physics (ISSN 0324-8313), vol. 29, no. 2, 1988, p. 177-192. refs  
Copyright

The dynamic properties of an aircraft piston engine assembly composed of a crankshaft and an airscrew are analyzed by the finite element method. The model consists of deformable beam and shaft elements with bending vibration in two mutually perpendicular planes, torsional vibration about the local rigidity axis, and tension vibration. The structural scheme is composed of elements of a shaft rotating about its axis, elements of a shaft rotating in an eccentric manner, beam elements of the crank and the airscrew rotating in a field of centrifugal forces, and a rigid element representing the hub or the airscrew hub with blades (if the computer memory is limited). By applying the method of deformable finite elements in the displacement version and the method of rigid finite elements, the equations of dynamic equilibrium are derived for shaft and beam elements. S.A.V.

N90-10034\*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

##### PERFORMANCE POTENTIAL OF AN ADVANCED TECHNOLOGY MACH 3 TURBOJET ENGINE INSTALLED ON A CONCEPTUAL HIGH-SPEED CIVIL TRANSPORT

SHELBY J. MORRIS, JR., KARL A. GEISELHART (Planning Research Corp., Hampton, VA.), and PETER G. COEN Washington Nov. 1989 31 p  
(NASA-TM-4144; L-16531; NAS 1.15:4144) Avail: NTIS HC A03/MF A01 CSCL 21/5

The performance of an advanced technology conceptual turbojet optimized for a high-speed civil aircraft is presented. This information represents an estimate of performance of a Mach 3 Brayton (gas turbine) cycle engine optimized for minimum fuel burned at supersonic cruise. This conceptual engine had no noise or environmental constraints imposed upon it. The purpose of this data is to define an upper boundary on the propulsion performance for a conceptual commercial Mach 3 transport design. A comparison is presented demonstrating the impact of the technology proposed for this conceptual engine on the weight and other characteristics of a proposed high-speed civil transport. This comparison indicates that the advanced technology turbojet described could reduce the gross weight of a hypothetical Mach 3 high-speed civil transport design from about 714,000 pounds to about 545,000 pounds. The aircraft with the baseline engine and the aircraft with the advanced technology engine are described.

Author

N90-10035# National Aerospace Lab., Tokyo (Japan).

##### CYCLE ANALYSIS OF SCRAMJET ENGINES

TAKESHI KANDA, GORO MASUYA, and YOSHIO WAKAMATSU Oct. 1988 16 p In JAPANESE; ENGLISH summary  
(NAL-TR-1002; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

Engine cycles for airframe-integrated scramjets employing hydrogen fuel are analyzed to investigate regenerative engine cooling characteristics, required pump exit pressure, and overall engine thrust. An expander cycle and a gas generator (G.G.) cycle are examined. It is found that the engine can function with either of these cycles. For flights at high Mach numbers, it is found that the hydrogen flow rate required for engine cooling exceeds the stoichiometric flow rate needed for combustion. The specific impulse of the G.G. cycle is lower than that of the expander cycle because oxygen is needed for the gas generator. If an advanced refractory material is available for the G.G. cycle engine wall, it is possible to decrease the hydrogen flow rate needed for

engine cooling and thus to enlarge the range of engine operation.

Author

N90-10036\*# Detroit Diesel Allison, Indianapolis, IN. Dept. of Engineering.

##### ADVANCED TURBINE TECHNOLOGY APPLICATIONS PROJECT (ATTAP) Annual Report, Nov. 1987 - Dec. 1988

1 Jun. 1989 106 p  
(Contract DEN3-336; DE-AI01-85CE-50111)  
(NASA-CR-185133; NAS 1.26:185133; EDR-14232;  
DOE/NASA/0336-1) Avail: NTIS HC A06/MF A01 CSCL 21/5

ATTAP activities during the past year were highlighted by an extensive materials assessment, execution of a reference powertrain design, test-bed engine design and development, ceramic component design, materials and component characterization, ceramic component process development and fabrication, component rig design and fabrication, test-bed engine fabrication, and hot gasifier rig and engine testing. Materials assessment activities entailed engine environment evaluation of domestically supplied radial gasifier turbine rotors that were available at the conclusion of the Advanced Gas Turbine (AGT) Technology Development Project as well as an extensive survey of both domestic and foreign ceramic suppliers and Government laboratories performing ceramic materials research applicable to advanced heat engines. A reference powertrain design was executed to reflect the selection of the AGT-5 as the ceramic component test-bed engine for the ATTAP. Test-bed engine development activity focused on upgrading the AGT-5 from a 1038 C (1900 F) metal engine to a durable 1371 C (2500 F) structural ceramic component test-bed engine. Ceramic component design activities included the combustor, gasifier turbine static structure, and gasifier turbine rotor. The materials and component characterization efforts have included the testing and evaluation of several candidate ceramic materials and components being developed for use in the ATTAP. Ceramic component process development and fabrication activities were initiated for the gasifier turbine rotor, gasifier turbine vanes, gasifier turbine scroll, extruded regenerator disks, and thermal insulation. Component rig development activities included combustor, hot gasifier, and regenerator rigs. Test-bed engine fabrication activities consisted of the fabrication of an all-new AGT-5 durability test-bed engine and support of all engine test activities through instrumentation/build/repair. Hot gasifier rig and test-bed engine testing activities were performed.

Author

N90-10037\*# General Electric Co., Cincinnati, OH. Aircraft Engines.

##### PMR GRAPHITE ENGINE DUCT DEVELOPMENT Final Report

C. L. STOTLER and S. A. YOKEL Aug. 1989 190 p LIMITED REPRODUCIBILITY: More than 20% of this document may be affected by foldouts  
(Contract NAS3-21854)  
(NASA-CR-182228; NAS 1.26:182228) Avail: NTIS HC A09/MF A01 CSCL 21/5

The objective was to demonstrate the cost and weight advantages that could be obtained by utilizing the graphite/PMR15 material system to replace titanium in selected turbofan engine applications. The first component to be selected as a basis for evaluation was the outer bypass duct of the General Electric F404 engine. The operating environment of this duct was defined and then an extensive mechanical and physical property test program was conducted using material made by processing techniques which were also established by this program. Based on these properties, design concepts to fabricate a composite version of the duct were established and two complete ducts fabricated. One of these ducts was proof pressure tested and then run successfully on a factory test engine for over 1900 hours. The second duct was static tested to 210 percent design limit load without failure. An improved design was then developed which utilized integral composite end flanges. A complete duct was fabricated and successfully proof pressure tested. The net results of this effort showed that a composite version of the outer duct would be 14 percent lighter and 30 percent less expensive than



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the titanium duct. The other type of structure chosen for investigation was the F404 fan stator assembly, including the fan stator vanes. It was concluded that it was feasible to utilize composite materials for this type structure but that the requirements imposed by replacing an existing metal design resulted in an inefficient composite design. It was concluded that if composites were to be effectively used in this type structure, the design must be tailored for composite application from the outset. Author

**N90-10040#** Aeronautical Research Labs., Melbourne (Australia).

### **REPORT ON AN OVERSEAS VISIT, JUNE 1988 Propulsion Technical Memorandum**

D. E. GLENNY Feb. 1989 39 p  
(AD-A210374; ARL-PROP-TM-455; DODA-AR-005-575) Avail: NTIS HC A03/MF A01 CSCL 13/8

A visit was undertaken in June 1988 to attend the 71st Symposium of the AGARD Propulsion and Energetics Panel (PEP) on Engine Condition Monitoring - Technology and Experience held in Quebec Canada and to visit selected industry, military and research facilities in Canada and USA. The latter visits were to discuss methods for assessing gas turbine performance when operating with and without faulty components. A total of 8 establishments were visited in Canada and USA. In the course of the visit an opportunity was taken to hold preliminary discussions on the establishment of Key Technical Areas (KTA) in the newly formed TTCP HTP-7. At the conclusion of the tour a visit was made to the Singapore Ministry of Defence (and Singapore Aircraft Industries) to discuss aspects of Performance Monitoring and the installation of the GE F404 in the Skyhawks of the Royal Singapore Air Force. GRA

**N90-10041#** Aeronautical Research Labs., Melbourne (Australia).

### **AN APPRAISAL OF A NUMBER OF POWER ASSESSMENT PROCEDURES BEING PROPOSED FOR USE IN CHINOOK-LYCOMING T55 ENGINE**

D. E. GLENNY Feb. 1989 27 p  
(AD-A210482; ARL-PROP-TM-454; DODA-AR-005-574) Avail: NTIS HC A03/MF A01 CSCL 21/5

In response to a request from RAAF HQSC a number of power assessment procedures for application to the Chinook-Lycoming T55 engine were examined. The most satisfactory procedure was found to be the RAF Power Assurance Check (PAC). However because the method is not fully defined, and its monitoring period is currently set at 25 hour intervals, the procedure will require some refinement before it can be fully utilized. The potentially most attractive procedure is the Power Assurance Test (PAT) proposed in conjunction with the retrofitting of a full authority digital engine control (FADEC) to the T55-L11 engine. This latter procedure has a number of deficiencies associated with it and the RAAF should monitor its development closely before any decision is made to implement the procedures on a regular basis. GRA

**N90-10042\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **STATIC AEROELASTIC ANALYSIS FOR GENERIC CONFIGURATION AIRCRAFT**

IN LEE, HIROKAZU MIURA, and MLADEN K. CHARGIN Jun. 1987 53 p  
(NASA-TM-89423; A-87091; NAS 1.15:89423) Avail: NTIS HC A04/MF A01 CSCL 21/5

A static aeroelastic analysis capability that can calculate flexible air loads for generic configuration aircraft was developed. It was made possible by integrating a finite element structural analysis code (MSC/NASTRAN) and a panel code of aerodynamic analysis based on linear potential flow theory. The framework already built in MSC/NASTRAN was used and the aerodynamic influence coefficient matrix is computed externally and inserted in the NASTRAN by means of a DMAP program. It was shown that deformation and flexible airloads of an oblique wing aircraft can be calculated reliably by this code both in subsonic and supersonic

speeds. Preliminary results indicating importance of flexibility in calculating air loads for this type of aircraft are presented.

Author

### **N90-10043\*# Hamilton Standard, Windsor Locks, CT. LARGE SCALE PROP-FAN STRUCTURAL DESIGN STUDY. VOLUME 1: INITIAL CONCEPTS**

L. C. BILLMAN, C. J. GRUSKA, R. M. LADDEN, D. K. LEISHMAN, and J. E. TURNBERG 1988 258 p  
(Contract NAS3-22394)  
(NASA-CR-174992; NAS 1.26:174992; HSER-11518-VOL-1)  
Avail: NTIS HC A12/MF A01 CSCL 21/5

In recent years, considerable attention has been directed toward improving aircraft fuel consumption. Studies have shown that the inherent efficiency advantage that turboprop propulsion systems have demonstrated at lower cruise speeds may now be extended to the higher speeds of today's turbofan and turbojet-powered aircraft. To achieve this goal, new propeller designs will require features such as thin, high speed airfoils and aerodynamic sweep, features currently found only in wing designs for high speed aircraft. This is Volume 1 of a 2 volume study to establish structural concepts for such advanced propeller blades, to define their structural properties, to identify any new design, analysis, or fabrication techniques which were required, and to determine the structural tradeoffs involved with several blade shapes selected primarily on the basis of aero/acoustic design considerations. The feasibility of fabricating and testing dynamically scaled models of these blades for aeroelastic testing was also established. The preliminary design of a blade suitable for flight use in a testbed advanced turboprop was conducted and is described in Volume 2. Author

### **N90-10044\*# Hamilton Standard, Windsor Locks, CT. LARGE SCALE PROP-FAN STRUCTURAL DESIGN STUDY. VOLUME 2: PRELIMINARY DESIGN OF SR-7**

L. C. BILLMAN, C. J. GRUSKA, R. M. LADDEN, D. K. LEISHMAN, and J. E. TURNBERG 1988 282 p  
(Contract NAS3-22394)  
(NASA-CR-174993; NAS 1.26:174993; HSER-11518-VOL-2)  
Avail: NTIS HC A13/MF A01 CSCL 21/5

In recent years, considerable attention has been directed toward improving aircraft fuel consumption. Studies have shown that the inherent efficiency advantage that turboprop propulsion systems have demonstrated at lower cruise speeds may now be extended to the higher speeds of today's turbofan and turbojet-powered aircraft. To achieve this goal, new propeller designs will require features such as thin, high speed airfoils and aerodynamic sweep, features currently found only in wing designs for high speed aircraft. This is Volume 2 of a 2 volume study to establish structural concepts for such advanced propeller blades, to define their structural properties, to identify any new design, analysis, or fabrication techniques which were required, and to determine the structural tradeoffs involved with several blade shapes selected primarily on the basis of aero/acoustic design considerations. The feasibility of fabricating and testing dynamically scaled models of these blades for aeroelastic testing was also established. The preliminary design of a blade suitable for flight use in a testbed advanced turboprop was conducted and is described. Author

### **N90-10045\*# Hamilton Standard, Windsor Locks, CT. LARGE-SCALE ADVANCED PROP-FAN (LAP) HIGH SPEED WIND TUNNEL TEST REPORT**

WILLIAM A. CAMPBELL, HAROLD S. WAINAUSKI, and PETER J. ARSENEAUX Jul. 1988 199 p  
(Contract NAS3-23051)  
(NASA-CR-182125; NAS 1.26:182125; HSER-11894) Avail: NTIS HC A09/MF A01 CSCL 21/5

High Speed Wind Tunnel testing of the SR-7L Large Scale Advanced Prop-Fan (LAP) is reported. The LAP is a 2.74 meter (9.0 ft) diameter, 8-bladed tractor type rated for 4475 KW (6000 SHP) at 1698 rpm. It was designated and built by Hamilton Standard under contract to the NASA Lewis Research Center. The LAP

employs thin swept blades to provide efficient propulsion at flight speeds up to Mach .85. Testing was conducted in the ONERA S1-MA Atmospheric Wind Tunnel in Modane, France. The test objectives were to confirm that the LAP is free from high speed classical flutter, determine the structural and aerodynamic response to angular inflow, measure blade surface pressures (static and dynamic) and evaluate the aerodynamic performance at various blade angles, rotational speeds and Mach numbers. The measured structural and aerodynamic performance of the LAP correlated well with analytical predictions thereby providing confidence in the computer prediction codes used for the design. There were no signs of classical flutter throughout all phases of the test up to and including the 0.84 maximum Mach number achieved. Steady and unsteady blade surface pressures were successfully measured for a wide range of Mach numbers, inflow angles, rotational speeds and blade angles. No barriers were discovered that would prevent proceeding with the PTA (Prop-Fan Test Assessment) Flight Test Program scheduled for early 1987. Author

**N90-10046\*#** Hamilton Standard, Windsor Locks, CT.  
**LARGE-SCALE ADVANCED PROP-FAN (LAP) TECHNOLOGY ASSESSMENT REPORT**  
 C. L. DEGEORGE Sep. 1988 102 p  
 (Contract NAS3-23051)  
 (NASA-CR-182142; NAS 1.26:182142; HSER-11804) Avail: NTIS HC A06/MF A01 CSCL 21/5

The technologically significant findings and accomplishments of the Large Scale Advanced Prop-Fan (LAP) program in the areas of aerodynamics, aeroelasticity, acoustics and materials and fabrication are described. The extent to which the program goals related to these disciplines were achieved is discussed, and recommendations for additional research are presented. The LAP program consisted of the design, manufacture and testing of a near full-scale Prop-Fan or advanced turboprop capable of operating efficiently at speeds to Mach .8. An aeroelastically scaled model of the LAP was also designed and fabricated. The goal of the program was to acquire data on Prop-Fan performance that would indicate the technology readiness of Prop-Fans for practical applications in commercial and military aviation. Author

**N90-10047\*#** General Electric Co., Cincinnati, OH. Aircraft Engines Div.  
**FULL SCALE TECHNOLOGY DEMONSTRATION OF A MODERN COUNTERROTATING UNDUCTED FAN ENGINE CONCEPT: COMPONENT TEST**  
 Dec. 1987 109 p  
 (Contract NAS3-24210)  
 (NASA-CR-180868; NAS 1.26:180868) Avail: NTIS HC A06/MF A01 CSCL 21/5

The UDF trademark (Unducted Fan) engine is a new aircraft engine concept based on an ungeared, counterrotating, unducted, ultra-high-bypass turbofan configuration. This engine is being developed to provide a high thrust-to-weight ratio powerplant with exceptional fuel efficiency for subsonic aircraft application. This report covers the testing of pertinent components of this engine such as the fan blades, control and actuation system, turbine blades and spools, seals, and mixer frame. Author

**N90-10048\*#** General Electric Co., Cincinnati, OH. Aircraft Engines Div.  
**FULL SCALE TECHNOLOGY DEMONSTRATION OF A MODERN COUNTERROTATING UNDUCTED FAN ENGINE CONCEPT. DESIGN REPORT**  
 Dec. 1987 368 p  
 (Contract NAS3-24210)  
 (NASA-CR-180867; NAS 1.26:180867) Avail: NTIS HC A16/MF A01 CSCL 21/5

The Unducted Fan engine (UDF trademark) concept is based on an ungeared, counterrotating, unducted, ultra-high-bypass turbofan configuration. This engine is being developed to provide a high thrust-to-weight ratio power plant with exceptional fuel efficiency for subsonic aircraft application. This report covers the design methodology and details for the major components of this

engine. The design intent of the engine is to efficiently produce 25,000 pounds of static thrust while meeting life and stress requirements. The engine is required to operate at Mach numbers of 0.8 or above. Author

**N90-10049\*#** General Electric Co., Cincinnati, OH. Aircraft Engines Div.  
**FULL SCALE TECHNOLOGY DEMONSTRATION OF A MODERN COUNTERROTATING UNDUCTED FAN ENGINE CONCEPT. ENGINE TEST**  
 Dec. 1987 340 p  
 (Contract NAS3-24210)  
 (NASA-CR-180869; NAS 1.26:180869) Avail: NTIS HC A15/MF A01 CSCL 21/5

The Unducted Fan (UDF) engine is an innovative aircraft engine concept based on an ungeared, counterrotating, unducted, ultra-high-bypass turbofan configuration. This engine is being developed to provide a high thrust-to-weight ratio power plant with exceptional fuel efficiency for subsonic aircraft application. This report covers the successful ground testing of this engine. A test program exceeding 100-hr duration was completed, in which all the major goals were achieved. The following accomplishments were demonstrated: (1) full thrust (25,000 lb); (2) full counterrotating rotor speeds (1393+ rpm); (3) low specific fuel consumption (less than 0.24 lb/hr/lb); (4) new composite fan design; (5) counterrotation of structures, turbines, and fan blades; (6) control system; (7) actuation system; and (8) reverse thrust. Author

**N90-10195#** General Electric Co., Cincinnati, OH. Aircraft Engines.  
**DYNAMIC INSTABILITY CHARACTERISTICS OF AIRCRAFT TURBINE ENGINE COMBUSTORS**  
 M. J. KENWORTHY, D. W. BAHR, P. MUNGUR, D. L. BURRUS, J. M. MEHTA, and ANTHONY J. CIFONE (Naval Air Propulsion Test Center, Trenton, NJ.) In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 13 p Apr. 1989  
 Copyright Avail: NTIS HC A14/MF A01

Many aircraft turbine engine combustors exhibit dynamic instabilities at subidle and idle operating conditions. These instabilities can result in objectionable noise and, in some instances, compressor stall problems. To permit analytical assessments of these phenomena, an aeroacoustic model of these combustor instabilities was developed. To calibrate and validate this model, sector rig tests of the CF6-80A engine combustor were conducted. In these tests, the frequencies and amplitudes of the instabilities and the acoustic characteristics of the combustor were measured. Additional tests in a F101/F110/CFM56 sector combustor rig are planned. The test results compare well with the theory. The following conclusions are drawn from the portion of the work completed to date: (1) audible noise is a resonant acoustic wave within the cavity as predicted by the analytical model; (2) the acoustic wave responds strongly at the fuel-air ratio with the optimum time lag between the fuel injector and the heat release region, consistent with the analytical model; and (3) the analytical model predictions are in generally good agreement with the CF6-80A combustor test data, but further experiments with better defined end conditions are being obtained for a more complete validation. Author

**N90-10199#** Naval Weapons Center, China Lake, CA. Airbreathing Propulsion Branch.  
**RECENT DEVELOPMENTS IN RAMJET PRESSURE OSCILLATION TECHNOLOGY**  
 P. A. CHUN, J. A. LOUNDAGIN, J. A. NABITY, and S. E. AYLER In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 13 p Apr. 1989  
 Copyright Avail: NTIS HC A14/MF A01

Dynamic matching of a supersonic inlet and combustor is a major consideration in ramjet propulsion development. The inlet shock system present under supersonic speeds must be kept stable under all engine operating conditions. An unstable shock system could result in inlet unstart and/or buzz and undesirable pressure oscillations in the ramjet engine. To date, there is no technique

## 07 AIRCRAFT PROPULSION AND POWER

for determining if a particular ramjet engine configuration will have combustion-induced pressure oscillations. Current experimental and theoretical techniques applied to the characterization of liquid fuel ramjet combustors are summarized. Comparisons between steady-state and dynamic data are provided to show how both types of information are used to interpret engine behavior.

Author

**N90-10202\*#** Flow Research, Inc., Kent, WA.

### **NUMERICAL SIMULATION OF PRESSURE OSCILLATIONS IN A RAMJET COMBUSTOR**

WEN-HUEI JOU and SURESH MENON /In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 25 p Apr. 1989 Sponsored in part by NASA. Lewis Research Center; and by NASA. Ames Research Center (Contract N00014-84-C-0359)

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Large-eddy simulations of compressible cold flow in a ramjet combustor configuration were performed. The objectives were to investigate the mechanisms for vortex-acoustic interaction in such a device and to develop a simulation method that can be extended to cases with combustion heat release to study combustion instability. From the simulation, it was found that the separated shear layer rolls up into concentrated vortices that merge to form large coherent structures. These vortices interact with the choked nozzle downstream to produce an axial acoustic dipole. The spectrum of the pressure fluctuation at the base of the backward-facing step shows that there are two types of oscillations: an acoustic resonant mode and a vortex-acoustic coupled mode. Based on the flow physics observed in the simulations, a simple one-dimensional model for the vortex-acoustic coupled mode was proposed. The eigenvalue problem based on this model was solved to obtain the frequency of the coupled mode.

Author

**N90-10203#** Office National d'Etudes et de Recherches Aeronautiques, Paris (France).

### **NUMERICAL SIMULATION OF UNSTEADY COMBUSTION IN A DUMP COMBUSTOR [SIMULATION NUMERIQUE DU FONCTIONNEMENT INSTATIONNAIRE D'UN FOYER A ELARGISSEMENT BRUSQUE]**

F. GARNIER, B. LABEGORRE, M. SERRANO, and A. LAVERDANT /In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 28 p Apr. 1989 In FRENCH; ENGLISH summary

Copyright Avail: NTIS HC A14/MF A01

Basic investigations can be of great interest in the control of high frequency combustion instability in ramjets, in particular by identification of amplifying and damping mechanism of instabilities and of their coupling. With the advent of vectorized computers and the progress of numerical methods, simulation of unsteady, biphasic and three-dimensional combustion is now possible. In this perspective, ONERA has undertaken the adaptation of a computer code, KIVA, precendently developed by the Los Alamos National Laboratory for diesel engines study; this adaptation is essentially concerned with the introduction of inflow and outflow. The application is made on a dump combustor with liquid fuel injection. A detailed description of physico-chemical mechanism involved is presented and the first numerical results obtained are compared with similar ones.

Author

**N90-10204#** California State Univ., Sacramento. Dept. of Mechanical Engineering.

### **VERY-LOW-FREQUENCY OSCILLATIONS IN LIQUID-FUELED RAMJETS**

FREDERICK H. REARDON /In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 12 p Apr. 1989 (Contract F33615-81-C-2078)

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Very-low-frequency (bulk-mode) oscillations were studied, making use of experimental data gathered at the Air Force Wright Aeronautical Laboratories. Only those oscillations in which the acoustic resonance characteristics of the combustor were not excited were considered. More than 200 cases of such oscillations

in coaxial-dump combustors were examined. Correlations of oscillation incidence, frequency and amplitude were made in terms of design and operating parameters, including inlet diameter and length, combustor diameter and length-to-diameter ratio, air inlet temperature and fuel-air ratio. An analytical model was developed with which the effects of various oscillation driving mechanisms were examined and compared with the experimental data. Mechanisms considered were: combustion rate fluctuations resulting from fluctuating flow rates of fuel and air, combustion energy release rate variations due to pressure and temperature fluctuations in the flame zone, distortion of the flame zone by vortices shed at the dump plane, generation of an oscillating pressure field by vortex shedding at the dump plane interacting with the exhaust nozzle contraction, and entropy (convective) waves, resulting from fuel/air ratio oscillations, that reflect from the nozzle as pressure waves. Calculations using the analytical model showed agreement with experimental results for nearly 70 percent of the tests examined. The vortex and entropy wave mechanisms did not substantially improve the model's predictive ability.

Author

**N90-10206#** Naval Research Lab., Washington, DC. Lab. for Computational Physics and Fluid Dynamics.

### **ACOUSTIC-VORTEX-CHEMICAL INTERACTIONS IN AN IDEALIZED RAMJET**

K. KAILASANATH, J. H. GARDNER, J. P. BORIS, and ELAINE S. ORAN /In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 13 p Apr. 1989 Sponsored in part by Navy

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A potentially important source of large pressure oscillations in combustors is an instability induced by the interactions between large-scale vortex structures, acoustic waves, and chemical energy release. To study these interactions, time-dependent, compressible numerical simulations of the flow field in an idealized ramjet consisting of an axisymmetric inlet and combustor and a choked nozzle were performed. These simulations have allowed the isolation of the interactions between acoustic waves and large-scale vortex structures and then to study the effects of energy release on the flow field. A number of parameters such as inflow Mach number, inlet and combustor acoustics and energy release rates have been systematically varied in the simulations. A summary of the observations from these various simulations are presented in this paper. The nonreactive flow calculations show complex interactions among the natural instability frequency of the shear layer at the inlet-combustor junction and the acoustics of both the inlet and the combustor. Vortex shedding usually occurs at the natural instability frequency of the initially laminar shear layer but vortex mergings are affected by the acoustic frequencies of the ramjet. When the frequency of the first longitudinal acoustic mode of the combustor is near the natural instability frequency of the shear layer, then vortex shedding is observed at the acoustic frequency. In many cases the entire flow oscillates at a low frequency which corresponds to that of a quarter-wave mode in the inlet. In these cases, the vortex-merging patterns in the combustor can be explained on the basis of an interaction between the acoustics of the inlet and the combustor. For the particular reactive flow case discussed, energy release alters the flow field substantially. In the first cycle after ignition, fluid expansion due to energy release quickly destroys the pattern of vortex mergings observed in the cold flow and a new pattern emerges that is dominated by a large vortex. In subsequent cycles, most of the energy release occurs after vortex mergings have produced this large vortex. Energy release in this large vortex is in phase with the pressure oscillation over a substantial region of the combustor. This results in the observed amplification of the low-frequency oscillations and leads to combustion instability.

Author

**N90-10891\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

### **ADVANCED TECHNOLOGIES IMPACT ON COMPRESSOR DESIGN AND DEVELOPMENT: A PERSPECTIVE**

CALVIN L. BALL Sep. 1989 18 p Presented at Aerotech '89,

Anaheim, CA, 25-28 Sep. 1989; sponsored by SAE (NASA-TM-102341; E-5039; NAS 1.15:102341) Avail: NTIS HC A03/MF A01 CSDL 21/5

A historical perspective of the impact of advanced technologies on compression system design and development for aircraft gas turbine applications is presented. A bright view of the future is projected in which further advancements in compression system technologies will be made. These advancements will have a significant impact on the ability to meet the ever-more-demanding requirements being imposed on the propulsion system for advanced aircraft. Examples are presented of advanced compression system concepts now being studied. The status and potential impact of transitioning from an empirically derived design system to a computationally oriented system are highlighted. A current NASA Lewis Research Center program to enhance this transitioning is described. Author

**N90-10893#** Pennsylvania State Univ., University Park. Dept. of Mechanical Engineering.

**ANALYTICAL STUDY OF MISTUNING/FRICTION/AERODYNAMICS INTERACTION IN A BLADED DISK ASSEMBLY** Final Report, May 1987 - Jan. 1989 ALOK SINHA and SHING CHEN 6 Feb. 1989 80 p (Contract AF-AFOSR-0142-87; AF PROJ. 2302) (AD-A211139; AFOSR-89-1059TR) Avail: NTIS HC A05/MF A01 CSDL 20/11

An analytical technique is shown to be valid for the computation of the statistics of a blade's vibratory amplitude when the distributions of modal parameters of a mistuned bladed disk assembly are non-Gaussian. The results from the analytical technique are compared with those from numerical simulations for triangular and uniform distributions. It was found that the probability density function of the amplitude is insensitive to the types of mistuning distributions. Next, an analytical technique was developed to efficiently compute the probability density function of the maximum amplitude on a mistuned bladed disk assembly. This technique uses the direct Taylor series expansion in terms of the perturbation in an amplitude as a function of perturbations in modal stiffnesses. The validity of the techniques has been corroborated by comparison with the results from numerical simulations. Lastly, the statistics of the forced response of a structurally and aerodynamically coupled bladed disk assembly were computed efficiently by the analytical technique. The results from the analytical technique agree well with those from numerical simulations. The effects of the following parameters on the statistics of the maximum amplitude were studied: the aerodynamic couplings among blades, the fluid density and the cascade stagger angle. GRA

## 08

### AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

**A90-10221**  
**ON THE 'INVERSE PHUGOID PROBLEM' AS AN INSTANCE OF NON-LINEAR STABILITY IN PITCH**

L. M. B. C. CAMPOS and A. J. N. M. AGUIAR (Lisboa, Universidade Tecnica, Lisbon, Portugal) Aeronautical Journal (ISSN 0001-9240), vol. 93, Aug.-Sept. 1989, p. 241-253. Research supported by the Junta Nacional de Investigacao Cientifica e Tecnologica and Instituto Nacional de Investigacao Cientifica. refs Copyright

An analytical method is presented for solving the 'inverse phugoid problem' of finding the control laws that keep an aircraft on a straight flight path by exactly canceling the phugoid instability. It is shown, in particular, that (1) flight at velocities below the lower steady flight speed, which is unstable, is difficult to maintain

due to fast divergence toward the stall and (2) for an initial velocity above the lower steady flight speed, there is convergence toward the higher steady flight speed. V.L.

**A90-10491\*#** National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

**A KNOWLEDGE-BASED SYSTEM DESIGN/INFORMATION TOOL FOR AIRCRAFT FLIGHT CONTROL SYSTEMS**

DALE A. MACKALL (NASA, Flight Research Center, Edwards, CA) and JAMES G. ALLEN (Charles Stark Draper Laboratories, Inc., Cambridge, MA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 110-125. refs (AIAA PAPER 89-2978) Copyright

Flight test experiences of the X-29 forward-swept wing, the advanced fighter technology integration (AFTI) F-16, and the highly maneuverable aircraft technology (HiMAT) programs are reviewed. Significant operating anomalies in these programs and the design errors which caused them are examined. The functions which a system design/information tool should provide to assist designers in avoiding errors are identified. C.D.

**A90-11124#**  
**ADAPTIVE AUTOPILOT DESIGN VIA MODEL EXPANSION METHOD**

CHUAN-CH'U DING, YUAN-SHIUAN LIAO (National Taiwan University, Taipei, Republic of China), and DI CHIU (Chung Shan Institute of Science and Technology, Taoyuan, Republic of China) Chinese Institute of Engineers, Journal (ISSN 0253-3839), vol. 12, July 1989, p. 439-449. refs

An equivalent time constant and a model-expansion method are introduced for the design of a synthetic-stabilization acceleration autopilot. In the autopilot control loop, an extended Kalman filter is employed to estimate the time-varying airframe parameters. The performance of the autopilot and the extended Kalman filter is investigated through computer simulations. It is found that the model expansion method can efficiently specify the gains of the autopilot control loop, and good command following characteristics of the autopilot have been obtained in the computer simulations. The results also show an acceptable estimation error for the extended Kalman filter. Author

**A90-12473**  
**AERODYNAMIC AND DYNAMIC PRINCIPLES OF HELICOPTER FLIGHT [OSNOVY AERODINAMIKI I DINAMIKI POLETA VERTOLETOV]**

ALEKSANDR M. VOLODKO Moscow, Izdatel'stvo Transport, 1988, 344 p. In Russian. refs Copyright

The fundamentals of helicopter flight aerodynamics and dynamics are reviewed. In particular, attention is given to the principal laws of aerodynamics; aerodynamics and dynamics of the rotor; power plant dynamics; and steady flight characteristics. The discussion also covers the maneuvering characteristics of helicopters, takeoff and landing, flight under complex conditions, and the aerodynamics of coaxial-rotor helicopters. V.L.

**A90-12481**  
**HELICOPTER DYNAMICS: LIMITING FLIGHT CONDITIONS [DINAMIKA VERTOLETA: PREDEL'NYE REZHIMY POLETA]**

ALEKSANDR S. BRAVERMAN and ALEKSANDR P. VAINTRUB Moscow, Izdatel'stvo Mashinostroenie, 1988, 280 p. In Russian. refs Copyright

Methods are presented for the mathematical modeling of limiting flight conditions with allowance for changes in the aerodynamic characteristics of the rotor and the helicopter as a whole under stall conditions during flight along curved paths. Topics discussed include methods for determining the aerodynamic characteristics of the rotor in mathematical modeling; modeling of helicopter flight dynamics; changes in rotor speed and flight velocity during maneuvers; and examples of flight path modeling. The discussion

also covers helicopter classes and flight performance requirements; conditions and methods of determining the limiting weight of helicopters of different classes; and determination of landing characteristics in the case of failure of all engines. V.L.

**A90-12764**

### IDENTIFICATION OF MATHEMATICAL DERIVATIVE MODELS FOR THE DESIGN OF A MODEL FOLLOWING CONTROL SYSTEM

JUERGEN KALETKA and WOLFGANG VON GRUENHAGEN (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 213-228. refs  
Copyright

Accurate mathematical models were required for the design of a model following control system for the DLR BO 105 fly-by-wire helicopter ATHeS (Advanced Technology Testing Helicopter System). These models were extracted from flight test data by system identification techniques. Conventional 6-DOF rigid-body models turned out to be not appropriate, because they cannot accurately represent the initial response characteristics of the helicopter. Therefore, an extended model with 8 DOF, including rotor dynamic effects, was derived and identified. Both identification and verification results demonstrate the improved short-term response of the extended model and prove its applicability for the control system design. Results obtained from in-flight simulation measurements confirm the reliability of the 8-DOF model Author

**A90-12765**

### IDENTIFICATION OF A COUPLED BODY/CONING/INFLOW MODEL OF PUMA VERTICAL RESPONSE IN THE HOVER

S. S. HOUSTON (Royal Aerospace Establishment, Flight Dynamics Div., Bedford, England) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 229-249. refs  
Copyright

An attempt is made to better understand helicopter behavior in the hover through the identification of a coupled three-degree-of-freedom model of the Puma aircraft. The model can be used to explain why quasi-steady theory fails to predict heave axis damping and control sensitivity. The verification of the model using an input dissimilar to that used in the identification process confirms that the Puma exhibits quasi-steady heave damping and control sensitivity significantly lower than that predicted by theory. K.K.

**A90-12766**

### IDENTIFICATION OF AN ADEQUATE MODEL FOR COLLECTIVE RESPONSE DYNAMICS OF A SEA KING HELICOPTER IN HOVER

R. A. FEIK and R. H. PERRIN (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 251-265. refs  
Copyright

A mathematical representation of a vertical acceleration response characteristics of a helicopter in hover has been developed, including blade flapping, inflow, and rotor speed dynamics. A Maximum Likelihood parameter estimation technique has been applied to assess the adequacy of the model, and to identify the relevant parameters, using flight data from a Sea King Mk 50 helicopter. A number of conclusions related to the validity of the modeling approach have resulted from comparisons between predicted and identified parameters, and further investigation of some aspects are indicated. Author

**A90-12767\*** Advanced Rotorcraft Technology, Inc., Mountain View, CA.

### IDENTIFICATION OF A COUPLED FLAPPING/INFLOW MODEL FOR THE PUMA HELICOPTER FROM FLIGHT TEST DATA

RONALD DU VAL, OFER BRUHIS, and JOHN GREEN (Advanced Rotorcraft Technology, Inc., Mountain View, CA) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 267-280. Research supported by NASA.  
Copyright

A model validation procedure is applied to a coupled flapping/inflow model of a PUMA helicopter blade. The structure of the baseline model is first established. Model structure and flight test data are checked for consistency. Parameters of the model are then identified from the flight test data. Author

**A90-12769\*** San Jose State Univ., CA.

### IDENTIFICATION OF ROTOR FLAPPING EQUATION OF MOTION FROM FLIGHT MEASUREMENTS WITH THE RSRA COMPOUND HELICOPTER

Jl C. WANG (San Jose State University, CA) and PETER D. TALBOT (NASA, Ames Research Center, Moffett Field, CA) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 295-309. refs  
(Contract NCC2-267)  
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The application of an integrated rotorcraft identification method to the linear modeling of rotor system dynamics is studied. Two approaches used to describe the rotor flapping parameters in the rotor state dynamic equations and the period coefficients of the blade flapping equation of motion are presented. In the first approach, the parameters are identified in the nonrotating reference frame; in the second, the blade equivalent damping and spring periodic coefficients as well as other periodic coefficients are identified in the rotating reference frame. K.K.

**A90-12771\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### ADVANCEMENTS IN FREQUENCY-DOMAIN METHODS FOR ROTORCRAFT SYSTEM IDENTIFICATION

MARK B. TISCHLER (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 327-342. refs  
Copyright

A new method for frequency-domain identification of rotorcraft dynamics is presented. Nonparametric frequency-response identification and parametric transfer-function modeling methods are extended to allow the extraction of state-space (stability and control derivative) representations. An interactive computer program DERIVID is described for the iterative solution of the multi-input/multi-output frequency-response matching approach used in the identification. Theoretical accuracy methods are used to determine the appropriate model structure and degree-of-confidence in the identified parameters. The method is applied to XV-15 tilt-rotor aircraft data in hover. Bare-airframe stability and control derivatives for the lateral/directional dynamics are shown to compare favorably with models previously obtained using time-domain identification methods and the XV-15 simulation program. Author

**A90-12772**

### A FREQUENCY-DOMAIN SYSTEM IDENTIFICATION APPROACH TO HELICOPTER FLIGHT MECHANICS MODEL VALIDATION

C. G. BLACK and D. J. MURRAY-SMITH (Glasgow, University, Scotland) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 343-368. Research supported by the Ministry of Defence Procurement Executive. refs  
Copyright

The development of methods for the validation of complex nonlinear models of helicopter dynamics using measured flight data is discussed. The transformation to the frequency domain is addressed as well as equation-error methods in the frequency domain. Advantages of the methodology include the use of a restricted frequency range for the estimation of parameters of the rigid-body model and the incorporation of time delays into the model. K.K.

**A90-12775**

### EXPERIENCE WITH MULTI-STEP TEST INPUTS FOR HELICOPTER PARAMETER IDENTIFICATION

D. LEITH and D. J. MURRAY-SMITH (Glasgow, University, Scotland) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p.

## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

403-412. refs

Copyright

A test input design method developed to provide test signals with good properties for helicopter parameter identification is described. The features that should be present in the autospectrum of a desirable test signal are presented. Data on 1221 and double-doublet inputs are analyzed. K.K.

**A90-12872**

### **AIRPLANE DESIGN. PART 7 - DETERMINATION OF STABILITY, CONTROL AND PERFORMANCE**

#### **CHARACTERISTICS: FAR AND MILITARY REQUIREMENTS**

JAN ROSKAM (Kansas, University, Lawrence) Ottawa, KS, Roskam Aviation and Engineering Corp., 1988, 369 p. refs

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A reference manual is presented whose purpose is to help in the ascertainment that aircraft designs meet mission performance as well as stability and control requirements. The topics addressed include: longitudinal controllability and trim, directional and lateral controllability and trim, minimum control speed, maneuvering flight, control during the takeoff ground run, control during the landing ground run, roll performance, high-speed characteristics, aeroelastic considerations, static longitudinal stability, static lateral and directional stability, dynamic longitudinal stability, dynamic lateral-directional stability, dynamic coupling, stall characteristics, spin characteristics, ride and comfort characteristics, and performance in stall, takeoff, climb, cruise, endurance and loiter, dive, maneuvering, descent and glide, and landing. C.D.

**N90-10075\*#** California Univ., Los Angeles. Dept. of Computer Science.

### **REAL-TIME SUPPORT FOR HIGH PERFORMANCE AIRCRAFT OPERATION Final Report, 1986 - 1988**

JACQUES J. VIDAL Jan. 1989 24 p

(Contract NAG2-302)

(NASA-CR-185475; NAS 1.26:185475) Avail: NTIS HC A03/MF A01 CSCL 01/3

The feasibility of real-time processing schemes using artificial neural networks (ANNs) is investigated. A rationale for digital neural nets is presented and a general processor architecture for control applications is illustrated. Research results on ANN structures for real-time applications are given. Research results on ANN algorithms for real-time control are also shown. K.C.D.

**N90-10894** Bristol Univ. (England).

### **THE ACTIVE CONTROL OF AN UNSTABLE CANARD AIRCRAFT Ph.D. Thesis**

DAVID A. COWLING 1988 216 p

Avail: Univ. Microfilms Order No. BRDX85245

The design of control systems which utilize the independence of a canard aircraft's 2 pitch control surfaces is investigated. Eigenstructure assignment is used to calculate the gains for simple feedback structures. To cater for the multiloop designs, robustness and system sensitivity measures and objectives are formulated in terms of the minimum values of the return difference and inverse return difference matrices. An optimization scheme is developed which links this analysis with the eigenstructure assignment design procedure. This method allows system eigenvalues to be fixed whilst the eigenvector assignment is used to optimize the robustness and sensitivity. Results indicate that even with the classical pitch rate demand system robustness can be improved and gains reduced, by the independent use of the control surfaces. Designs incorporating incidence feedback appear more robust and less sensitive to parameter changes than the pitch rate alone feedback, even though the performance is the same. Gust response analysis also suggests that the multiloop design has improved characteristics. Finally, the application of the methods is demonstrated on a gross maneuvering multimode system.

Dissert. Abstr.

**N90-10895** York Univ. (England).

### **AN ASSESSMENT OF ROBUSTNESS OF FLIGHT CONTROL SYSTEMS BASED ON VARIABLE STRUCTURE TECHNIQUES Ph.D. Thesis**

SARAH KATHERINE SPURGEON 1988 270 p

Avail: Univ. Microfilms Order No. BRDX84782

Variable Structure Control Systems (VSCS) have received considerable attention in recent years as a possible solution to the problem of controlling time-varying and uncertain systems. The aim of this research is to investigate the application of the theory of VSCS to the design of flight control systems. Chapter One presents all of the necessary aircraft background which is required to formulate the design procedures developed by this work. Chapter Two offers an introduction to the theory of VSCS. Robust control system design using eigenstructure assignment is the subject of Chapter Three; this work is central to the algorithmic VSCS design procedure which is shown to be most effective for the aircraft system. Chapter Four formulates a generalized design technique for VSCS and considers an assessment of the robustness of a VSCS scheme. Chapter Five presents an overview of the theory relating to variable structure model-following control laws. Having developed the necessary tools, the design of control laws for a number of different aircraft maneuvers is considered. Non-linear aircraft simulations are used throughout to assess the performance of the control schemes developed. Dissert Abstr.

## 09

## RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

**A90-10347#**

### **EXPERIMENTAL INVESTIGATION ON THE INTERFERENCE EFFECT OF FL-23 WIND TUNNEL WALL ON TRANSONIC FLUTTER**

QIZHENG LU, QING LI, and BO LU (China Aerodynamics Research and Development Center, Mianyang, People's Republic of China) Acta Aerodynamica Sinica (ISSN 0258-1825), vol. 7, Sept. 1989, p. 351-357. In Chinese, with abstract in English. refs

This paper gives the results of an experimental investigation in the FL-23 wind tunnel. Four dynamically similar plate half-models of a 60-deg delta wing in various sizes were used in the tests. The results showed that the critical transonic flutter dynamic pressure was increased by the wind tunnel interference, and that when the ratios of the model span to the tunnel width were 0.687, 0.600 and 0.512, the compressibility correction coefficient to the critical flutter velocity was reduced by 3.8, 2.5, and 1.4 percent, respectively. Variable porosity tests qualitatively demonstrated the results mentioned above. Author

**A90-11005#**

### **WAVE CANCELLATION PROPERTIES OF A SPLITTER-PLATE POROUS WALL CONFIGURATION**

G. M. ELFSTROM (DSMA International, Inc., Toronto, Canada), B. MEDVED (Vazduhoplovnotehnicki Institut, Belgrade, Yugoslavia), and W. J. RAINBIRD (Carleton University, Ottawa, Canada) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 920-924. Previously cited in issue 15, p. 2409, Accession no. A88-37914. refs

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**A90-11138#**

### **BREAKAGE OF FAN BLADES IN THE S1 WIND TUNNEL AT MONTANE-AVRIEUX**

MAURICE BAZIN and PIERRE MARION (ONERA, Chatillon-sous-Bagneux, France) (Subsonic Aerodynamic Testing



## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

Association, Annual Conference, 25th, San Diego, CA, June 27-29, 1989) ONERA, TP no. 1989-104, 1989, 33 p.  
(ONERA, TP NO. 1989-104)

An accident due to a fatigue crack initiated in a stiffener welded to the main spar of a wind tunnel blade and then propagating in the spar up to the point of failure is investigated. Detailed failure mode and effect analyses are conducted to give a better understanding of the problem along with improved blade design and monitoring. Optimization of monitoring systems on site and blade inspections during maintenance operation are considered, involving feasibility and laboratory verification of a prototype ultrasonic system to inspect the blade spar from its cavity. Evaluation of crack propagation time and available safety margin after detection of a defect is also discussed. C.E.

### A90-11140#

#### APPLICATION OF THE HYDROGEN BUBBLE VISUALIZATION METHOD TO THE WATER TUNNELS OF ONERA

M. GALLON (ONERA, Chatillon-sous-Bagneux, France) (International Symposium on Flow Visualization, 5th, Prague, Czechoslovakia, Aug. 21-25, 1989) ONERA, TP no. 1989-107, 1989, 9 p.  
(ONERA, TP NO. 1989-107)

The conventional hydrogen bubble method was adapted to the vertical tunnels of ONERA, and applied to various flows in order to facilitate analysis of the visualization. It allows the use of tracer injectors which create very little flow disturbance and noncontaminating tracers; in certain cases, it also allows quantitative analysis of the visualizations. Different test setups were considered: anode connected to the tunnel frame ground; cathode located upstream of the model; cathode on the model; the model itself; and 45 degree mirror downstream of the model. The applications demonstrated that the process is capable of visualizing the streamlines whose very irregular spacing should facilitate future analysis and processing of the resulting images. The process is also capable of graduating the space in time lines. C.E.

### A90-11159#

#### NEW ROTOR TEST RIG IN THE LARGE MODANE WIND TUNNEL

M. ALLONGUE (Aerospatiale, Division Helicopteres, Marignane, France), J.-P. DREVET, and J.-N. REMANDET (ONERA, Chatillon-sous-Bagneux, France) (European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989) ONERA, TP no. 1989-137, 1989, 16 p. refs  
(ONERA, TP NO. 1989-137)

From now on, helicopter rotor tests in the large S1MA wind tunnel at the Modane-Avrieux Center of ONERA will be conducted with a new 'BERH' helicopter rotor test rig. The qualification tests were run in November 1987 and the first industrial test campaign - the tenth in S1MA - was conducted in August 1988. This document presents the possibilities of this new device and some results obtained during the tenth test campaign. The new bench is technically different from the previous one as concerns its support structure, drive system and instrumentation. These modifications have improved test productivity and measurement accuracy. With this new system, five rotors were tested in less than three weeks. The test method was thoroughly changed to include two major advantages. First, it avoids having to interpolate several times when comparing rotors. Secondly, the blade stresses on two rotors at the same lift and propulsive force are compared. To allow this approach, a control aid program operates on line during the tests. During the tenth campaign, a large amount of data was generated, and the quality of the data was shown to be satisfactory. Author

### A90-11169#

#### CONNECTION OF STRUCTURES BY LABORATORY-GENERATED ELECTRICAL DISCHARGES [CONNEXION DE STRUCTURES PAR DES DECHARGES ELECTRIQUES DE LABORATOIRE]

G. LABAUNE, M. LEMISTRE, F. ISSAC, J. P. MOREAU, and J. C. ALLIOT (ONERA, Chatillon-sous-Bagneux, France) (Colloque sur la Compatibilite Electromagnetique, 5th, Evian, France, Sept. 12-14,

1989) ONERA, TP no. 1989-147, 1989, 7 p. In French. Research supported by DRET. refs  
(ONERA, TP NO. 1989-147)

An experimental study of the resistance of discharge channels has been performed in order to formulate the laws for the variation of resistance with atmospheric ionization and the expansion of the channel, with application to the calculation of electrical circuits in simulations of the effects of lightning on large objects. Resistance measurements have been obtained with a band pass of 3 MHz for intervals varying from 1 to 5 m. Empirical laws have also been derived for the variation of resistance with leading edge loads from 1 to 50 microseconds and various loading values of the generator. The experimental findings are compared with theoretical results. R.R.

### A90-12631#

#### A FULL SCALE, VSTOL, GROUND ENVIRONMENT TEST FACILITY

L. H. K. REED (Rolls-Royce, PLC, Bristol, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1228-1234. Research supported by the Ministry of Defence Procurement Executive.

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An open air test site has been developed in the UK to study the effects of energetic jets on the operational flexibility of VSTOL aircraft. The site comprises a dynamic lander rig for full-scale installed testing up to a vehicle weight of 25,000 lbs, together with two fixed performance beds and two installations for blowing rigs. A summary of testing along with the provisioning and development of the test facility is described. The UK plans expansion and modification of that site to a facility adequate for investigating technologies essential to future STOVL aircraft development. C.E.

### A90-12634#

#### TEST RIG FOR THE STUDY OF THE FLOW IN A ROTOR-STATOR SYSTEM

J. BASTART, A. E. BOURGUIGNON (SNECMA, Moissy-Cramayel, France), M. IZARD, D. DUTOYA, P. J. MICHARD (ONERA, Chatillon-sous-Bagneux, France) et al. IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1251-1258. refs  
(ONERA, TP NO. 1989-124) Copyright

A test rig designed to acquire aerodynamic and thermal data required to validate a computation code applicable to centripetal or centrifugal flows in the cavity between a stator and a rotating disk is described. Its dimensions and operating characteristics make it possible to reproduce conditions to those encountered in engines. An extensive instrumentation makes it possible to obtain the data required for computation code validation. The first tests revealed the good behavior of the computation code in case of the centrifugal flows, whereas simulation difficulties arose for centripetal flows. Tests will continue with athermal run and dimensional flow disturbing elements. C.E.

### N90-10883# Naval Air Test Center, Patuxent River, MD.

#### AIR COMBAT ENVIRONMENT TEST AND EVALUATION FACILITY (ACETEF)

R. R. SMULLEN and S. D. HARRIS In AGARD, Flight Test Techniques 3 p Jul. 1989

Copyright Avail: NTIS HC A18/MF A03

Recent combat experience has brought to light a critical need to assess the mission effectiveness of Naval aviation weapons systems and vehicles against a myriad of new threats. Flight testing is the primary source of data on the effectiveness of our aircraft and weapons, but flight testing is costly, and limited to only a few of the most crucial questions. Flight testing is also inherently a public event; it can be observed with impunity. Hence, flight testing is patently unsatisfactory for dealing with some issues related to



national security interests. Senior decision-makers in the Department of Defense (DOD) require objective, quantitative assessments of the effectiveness of the weapons and people against literally thousands of possible combinations of threat and contingency planning conditions. A revolutionary approach is needed to obtain the requisite data. The Naval Air Test Center (NAVAIRTESTCEN) has begun to develop an innovative system, known as the Air Combat Environment Test and Evaluation Facility (ACETEF), to meet this need. Author

**N90-10887#** British Aerospace Public Ltd. Co., Preston (England). Flight Test Instrumentation Data Processing Dept.

**FLIGHT TEST INSTRUMENTATION AND DATA PROCESSING AT BRITISH AEROSPACE, WARTON, U.K.**

ROGER E. PORTER and MICHAEL F. ARMOUR In AGARD, Flight Test Techniques 16 p Jul. 1989  
Copyright Avail: NTIS HC A18/MF A03

British Aerospace Warton was engaged in the development and testing of a wide range of military fighter aircraft including Jaguar, Tornado and the E.A.P. During the next decade Warton will be a major flight test center for the European Fighter Aircraft (EFA). An overview is given of the instrumentation and data processing facilities in current use, planned development for the next 10 years covering the proposed instrumentation system for EFA. It describes the ground station, computing hardware, specialized analysis capability, onboard equipment, the extensive use of telemetry for real time processing and intermaneuver analysis in real time. Also included are the facilities for integration of airborne data acquisition systems, together with procurement, automated calibration, and design and development. Author

**N90-10896#** Army Cold Regions Research and Engineering Lab., Hanover, NH.

**DEFINITION OF RESEARCH NEEDS TO ADDRESS AIRPORT PAVEMENT DISTRESS IN COLD REGIONS**

T. S. VINSON, R. L. BERG, I. ZOMERMAN, and W. HAAS May 1989 146 p  
(Contract DTFA01-84-Z-02038)  
(DOT/FAA/DS-89/13; CRREL-89-10) Avail: NTIS HC A07/MF A01

In early fall 1984, a questionnaire was sent to over 325 general aviation airports in cold regions. The results from over 200 responses were compiled and evaluated and over 20 airport managers contacted for additional details. Site visits were made to 36 airports to obtain additional information. The most common pavement problems identified were associated with nontraffic-related phenomena and include: (1) preexisting cracks reflecting through asphalt concrete overlays (in two years or less); (2) thermal cracking; and (3) longitudinal cracking (at a construction joint). Most of the airports experienced: (1) water pumping up through cracks and joints in the pavements during spring thaw; or (2) additional roughness due to differential frost heave in the winter and spring. Many pavement problems can be traced to the evolutionary history of general aviation airports and the lack of consideration for site drainage. Based on the recognition of these problems, several future research programs are identified. Author

**N90-10897#** Federal Aviation Administration, Atlantic City, NJ.

**HELIPORT SURFACE MANEUVERING TEST RESULTS**  
**Technical Note, Oct. 1987 - Jan. 1988**

ROSANNE M. WEISS, CHRISTOPHER J. WOLF, SCOTT L. ERLICHMAN, JOHN G. MORROW, and WALTER E. DICKERSON Jun. 1989 81 p  
(Contract FAA-T0701-R)  
(ACD-330; DOT/FAA/CT-TN88/30) Avail: NTIS HC A05/MF A01

During late fall 1987 and early spring 1988 flight tests were conducted at the Federal Aviation Administration (FAA) Technical Center's National Concepts Development and Demonstration Heliport. The purpose of these tests was to measure pilot perception of helicopter tip clearances for parking and taxiing maneuvers and to measure pilot performance during these

maneuvers. Over 100 parking and taxiing maneuvers were conducted using a UH-1H helicopter. The parking procedures were conducted under head, tail, and crosswind conditions, both with and without an obstacle in place. The taxiing procedures were carried out with a centerline, with only side markings, and with no ground markings. A ground based laser tracker system was used to track the taxiing procedures. Pilot subjective data in reference to these maneuvers were collected via a post-flight questionnaire. Pilot interviews were conducted at heliports across the country. These interviews gathered pilot views concerning rotor tip clearances for parking and hover taxiing maneuvers, ground markings for parking operations, and hover taxiing heights. The results of this activity are documented. The data collection and analysis methodology is described along with an objective as well as subjective issues. Statistical and graphical analysis of pilot performance and perception data and pilot subjective data are provided. Author

**N90-10898#** National Aerospace Lab., Tokyo (Japan). Flight Research Div.

**FLIGHT SIMULATOR EVALUATION OF A HEAD-DOWN DISPLAY**

KEIJI TANAKA and HIROYASU KAWAHARA May 1987 19 p  
In JAPANESE; ENGLISH summary  
(NAL-TM-573; ISSN-0452-2982; JTN-88-80068) Avail: NTIS HC A03/MF A01

A Head-Down Display (HDD) designed for the NAL (National Aerospace Laboratory) Quiet Short Take-Off and Landing (QSTOL) experimental aircraft ASUKA, was evaluated using the STOL Flight Simulator. The HDD employs a shadow-mask type color cathode ray tube (CRT), and utilizes the flexibility of computer graphics. The simulator evaluation of the HDD installed on the right instrument panel of the STOL simulator cockpit is described. In the experiment, performances of the following three types of approach and landing flights were compared: (1) flights with conventional instruments (left seat); (2) HDD without the STOL flight director (right seat); and (3) HDD with the flight director (right seat). The flight records as well as pilot comments indicated performance improvement with the aid of the STOL flight director, while no significant differences were observed between flight performances with conventional instruments and with HDD without the flight director. Suggestions to improve the display format, such as to provide better lateral and directional control cues, contributed to a modified display format which is to be evaluated as the next step of the HDD development program. NASDA

**N90-10899#** National Aerospace Lab., Tokyo (Japan). STOL Aircraft Project Group.

**FLIGHT SIMULATION TEST FACILITY: FUNCTION AND SPECIFICATION OF THE SIMULATOR COCKPIT SYSTEM**

HIROYASU KAWAHARA, MASANORI OKABE, AKIRA WATANABE, TOSHIO BANDO, and KAORU WAKAIRO Nov. 1987 69 p In JAPANESE  
(NAL-TM-577; ISSN-0452-2982; JTN-88-80069) Avail: NTIS HC A04/MF A01

Flight simulators for research and development are indispensable as design tools in the development phase of aircraft. The National Aerospace Laboratory (NAL) has used a flight simulator for tests and research regarding the development and revamping of various aircraft since 1963, improving its simulation accuracy and scale. The original simulator became old and was no longer able to meet the demands for higher simulation test accuracy or for large equipment to be simulated. For this reason, the NAL decided to install a flight simulation test facility fully utilizing the latest technology. The functions, configuration and performance of the simulated cockpit equipment manufactured in 1980 and 1981 are described. NASDA

## ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

**A90-10845**

**AN ANALYSIS OF THE POSSIBILITY OF EXPANDING THE INFORMATION BASE OF AN ADAPTIVE CONTROL SYSTEM FOR A FLIGHT VEHICLE SURROUNDED BY AN IONIZED GAS MEDIUM [ANALIZ VOZMOZHNOСТИ RASSHIRENIIA INFORMATSIONNOGO BAZISA ADAPTIVNOI SISTEMY UPRAVLENIIA LETATEL'NYM APPARATOM, OKRUZHENNYM IONIZIROVANNOM GAZOVOI SREDOI]**

A. I. LYSENKO and I. A. GALKIN IN: Adaptive automatic control systems. Number 16. Kiev, Izdatel'stvo Tekhnika, 1988, p. 20-24. In Russian. refs

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The paper is concerned with the possibility of obtaining and utilizing additional information on the air velocity of a descending flight vehicle under conditions of intensive aerodynamic braking. In particular, attention is given to an approach based on the measurement of the ionized gas velocity behind the shock wave front (i.e., between the flight vehicle body and the air compression shock) and recalculation of the measurements in terms of shock wave front velocity (i.e., velocity of the flight vehicle relative to air). The high accuracy of control achieved with this approach is demonstrated.

V.L.

**A90-11458**

**HYPERSONICS REVISITED (THE FIRST LESLIE BEDFORD LECTURE)**

J. L. STOLLERY Aerospace (UK) (ISSN 0305-0831), vol. 15, June 1988, p. 10-17. refs

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An evaluation is made of current understanding of the problems associated with atmospheric flight in the Mach 5-30 hypersonic regime in the earth's atmosphere, to an altitude of 80 km. Attention is given to the phenomena of kinetic heating, hot boundary layer transition from laminar to turbulent regimes, and hypersonic vehicle payload fraction considerations. A status evaluation is also made of such current hypersonic vehicle programs as that of the NASA Space Shuttle Orbiter, the ESA Hermes, the Japanese HOPE, Britain's HOTOL, and the NASA X-30 SSTOV; the range of available development and test facilities for hypersonic vehicle-related research efforts is also inventoried. SDI-related hypersonic vehicle possibilities are noted.

O.C.

**A90-11650**

**ROCKWELL'S SIMULATOR EMULATES NASP FLIGHT CHARACTERISTICS**

WILLIAM B. SCOTT Aviation Week and Space Technology (ISSN 0005-2175), vol. 131, Oct. 23, 1989, p. 50, 51, 53, 54, 56, 57.

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The highly integrated character of the NASP hypersonic cruise aircraft, whose design will achieve unprecedented levels of interdependence between aerodynamics, propulsion, and control systems, has required the development of a simulator laboratory for the complex systems that are to be incorporated in the NASP program's X-30 research aircraft. The simulator is being used for engineering, systems, and failure mode analyses as well as flight control and handling qualities development and flight test profile planning. Attention is given to a cockpit mirror viewing system concept, and simulations of powered and unpowered landing approaches.

O.C.

**A90-12209**

**THE SMALL PORTABLE GLOBAL POSITIONING SYSTEM TRACKING RANGE OF THE FUTURE**

CARL E. HOEFENER (Interstate Electronics Corp., Anaheim, CA) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 489-494.

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The rapid advancement of technology will enable the development of a miniature range tracking and telemetry system in the future. This system will be van mounted and capable of tracking three vehicles and displaying space position and telemetry data.

Author

**A90-12468**

**OPTIMIZATION OF THE OBSERVATIONS AND CONTROL OF AIRCRAFT [OPTIMIZATSIIA NABLIUDENIIA I UPRAVLENIIA LETATEL'NYKH APPARATOV]**

VENIAMIN V. MALYSHEV, MIKHAIL N. KRASIL'SHCHIKOV, and VALERII I. KARLOV Moscow, Izdatel'stvo Mashinostroenie, 1989, 312 p. In Russian. refs

Copyright

Problems related to the optimization of the measured parameters, navigational equipment operation, aircraft control, and combined operation of control and navigation equipment are analyzed. The problems considered rely on probabilistic optimality criteria, with varying availability of data on the uncontrolled factors, such as measurement errors and perturbations. A new generalized approach is proposed which makes it possible to reduce the initially nonlinear control problems to equivalent linear (with respect to phase variables) problems by using the analytical properties of the Riccati problem.

V.L.

**A90-12513#**

**SIMILARITY AND SCALE EFFECTS IN SOLID FUEL RAMJET COMBUSTORS**

ALON GANY (Technion - Israel Institute of Technology, Haifa) and RACHEL BEN-AROSH IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 127-139. refs

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Theoretical analysis has been conducted concerning the similarity conditions and scaling rules in solid fuel ramjet (SFRJ) combustors. Modeling the dominant, controlling combustion processes, it has been shown that the 'p-d scaling' method, often applied to gas turbine and liquid fuel ramjet combustors, is appropriate for SFRJ combustors as well. Hence, experimental data obtained from a laboratory-size apparatus can be applied to a full-scale system. Experimental investigations have demonstrated good agreement between the theoretical predictions and the tests, verifying the similarity model and its resulting scaling rules.

Author

**N90-10086\*#** Royal Aerospace Establishment, Farnborough (England).

**THE APPLICATION OF TSIM SOFTWARE TO ACT DESIGN AND ANALYSIS ON FLEXIBLE AIRCRAFT**

IAN W. KAYNES In NASA, Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 109-120 May 1989

Avail: NTIS HC A21/MF A01 CSDL 22/2

The TSIM software is described. This is a package which uses an interactive FORTRAN-like simulation language for the simulation on nonlinear dynamic systems and offers facilities which include: mixed continuous and discrete time systems, time response calculations, numerical optimization, automatic trimming of nonlinear aircraft systems, and linearization of nonlinear equations for eigenvalues, frequency responses and power spectral response evaluation. Details are given of the application of TSIM to the analysis of aeroelastic systems under the RAE Farnborough extension FLEX-SIM. The aerodynamic and structural data for the equations of motion of a flexible aircraft are prepared by a

preprocessor program for incorporation in TSIM simulations. Within the simulation, the flexible aircraft model may then be selected interactively for different flight conditions and modal reduction techniques applied. The use of FLEX-SIM is demonstrated by an example of the flutter prediction for a simple aeroelastic model. By utilizing the numerical optimization facility of TSIM, it is possible to undertake identification of required parameters in the TSIM model within the simulation. Author

**N90-10106\*#** Boeing Co., Seattle, WA.  
**MODIFYING HIGH-ORDER AEROELASTIC MATH MODEL OF A JET TRANSPORT USING MAXIMUM LIKELIHOOD ESTIMATION**

AMIR A. ANISSIPOUR and RUSSELL A. BENSON /in NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 583-629 May 1989  
 Avail: NTIS HC A21/MF A01 CSCL 22/2

The design of control laws to damp flexible structural modes requires accurate math models. Unlike the design of control laws for rigid body motion (e.g., where robust control is used to compensate for modeling inaccuracies), structural mode damping usually employs narrow band notch filters. In order to obtain the required accuracy in the math model, maximum likelihood estimation technique is employed to improve the accuracy of the math model using flight data. Presented here are all phases of this methodology: (1) pre-flight analysis (i.e., optimal input signal design for flight test, sensor location determination, model reduction technique, etc.), (2) data collection and preprocessing, and (3) post-flight analysis (i.e., estimation technique and model verification). In addition, a discussion is presented of the software tools used and the need for future study in this field. Author

**N90-10111\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**CONTROL LAW SYNTHESIS AND OPTIMIZATION SOFTWARE FOR LARGE ORDER AEROSERVOELASTIC SYSTEMS**

V. MUKHOPADHYAY, A. POTOTZKY, and THOMAS NOLL /in its Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 693-707 May 1989  
 Avail: NTIS HC A21/MF A01 CSCL 22/2

A flexible aircraft or space structure with active control is typically modeled by a large-order state space system of equations in order to accurately represent the rigid and flexible body modes, unsteady aerodynamic forces, actuator dynamics and gust spectra. The control law of this multi-input/multi-output (MIMO) system is expected to satisfy multiple design requirements on the dynamic loads, responses, actuator deflection and rate limitations, as well as maintain certain stability margins, yet should be simple enough to be implemented on an onboard digital microprocessor. A software package for performing an analog or digital control law synthesis for such a system, using optimal control theory and constrained optimization techniques is described. Author

**N90-10112\*#** Purdue Univ., West Lafayette, IN.  
**FLEXIBLE AIRCRAFT DYNAMIC MODELING FOR DYNAMIC ANALYSIS AND CONTROL SYNTHESIS**

DAVID K. SCHMIDT /in NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 709-743 May 1989  
 Avail: NTIS HC A21/MF A01 CSCL 22/2

The linearization and simplification of a nonlinear, literal model for flexible aircraft is highlighted. Areas of model fidelity that are critical if the model is to be used for control system synthesis are developed and several simplification techniques that can deliver the necessary model fidelity are discussed. These techniques include both numerical and analytical approaches. An analytical approach, based on first-order sensitivity theory is shown to lead not only to excellent numerical results, but also to closed-form analytical expressions for key system dynamic properties such as the pole/zero factors of the vehicle transfer-function matrix. The analytical results are expressed in terms of vehicle mass properties,

vibrational characteristics, and rigid-body and aeroelastic stability derivatives, thus leading to the underlying causes for critical dynamic characteristics. Author

**N90-10123\*#** Old Dominion Univ., Norfolk, VA.  
**OPTIMAL INTEGRAL CONTROLLER WITH SENSOR FAILURE ACCOMMODATION**

T. ALBERTS and T. HOULIHAN (Jonathan Corp., Norfolk, VA.) /in NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 1003-1023 May 1989  
 Avail: NTIS HC A21/MF A01 CSCL 22/2

An Optimal Integral Controller that readily accommodates Sensor Failure - without resorting to (Kalman) filter or observer generation - has been designed. The system is based on Navy-sponsored research for the control of high performance aircraft. In conjunction with a NASA developed Numerical Optimization Code, the Integral Feedback Controller will provide optimal system response even in the case of incomplete state feedback. Hence, the need for costly replication of plant sensors is avoided since failure accommodation is effected by system software reconfiguration. The control design has been applied to a particularly ill-behaved, third-order system. Dominant-root design in the classical sense produced an almost 100 percent overshoot for the third-order system response. An application of the newly-developed Optimal Integral Controller - assuming all state information available - produces a response with no overshoot. A further application of the controller design - assuming a one-third sensor failure scenario - produced a slight overshoot response that still preserved the steady state time-point of the full-state feedback response. The control design should have wide application in space systems. Author

**N90-10150\*#** Raytheon Co., Waltham, MA. Microwave and Power Tube Div.

**HISTORY AND STATUS OF BEAMED POWER TECHNOLOGY AND APPLICATIONS AT 2.45 GIGAHERTZ**

WILLIAM C. BROWN /in NASA. Langley Research Center, Second Beamed Space-Power Workshop p 171-185 Jul. 1989  
 Avail: NTIS HC A19/MF A01 CSCL 10/2

Various applications of beamed power technology are discussed. An experimental microwave powered helicopter, rectenna technology, the use of the Solar Power Satellite to beam energy to Earth via microwaves, the use of cyclotron resonance devices, microwave powered airships, and electric propulsion are discussed. Author

**N90-10904#** Joint Publications Research Service, Arlington, VA.  
**LANDING TESTS FOR BURAN SHUTTLE WITH JET ENGINE-EQUIPPED MOCK-UP**

STEPAN ANASTASOVICH MIKOYAN /in its JPRS Report: Science and Technology. USSR: Space p 50 28 Jun. 1989 Transl. into ENGLISH from Sovetskaya Latviya (Riga, USSR), 27 Jan. 1989 p 3

Copyright Avail: NTIS HC A06/MF A01

Problems of controlling unmanned flights of the reusable spaceship Buran and landing it in a gliding mode, without the use of engine thrust are discussed. Particular attention is devoted to the use of an operating mock-up of the Buran in rehearsing landings and training pilots. As compared with the Buran itself, this mock-up possesses features which ensure flight similar to that of a conventional airplane. The mock-up has four jet airplane engines which enable it to take off and climb to an altitude of 5 to 6 kilometers. It is equipped with a landing-gear retraction system and ejectable seats for two test-pilots. The mock-up is identical to the Buran in most other respects. The control systems of the two crafts are similar, which enabled the mock-up to make 16 landings in the automatic mode. Author

## CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

**A90-11126#****EFFECT OF PROTECTIVE COATINGS ON MECHANICAL PROPERTIES OF SUPERALLOYS**

REMY MEVREL (ONERA, Chatillon-sous-Bagneux, France) and JEAN-MARIE VEYS (Ministere de la Defense, Service Technique des Programmes Aeronautiques, Paris, France) (NATO, AGARD, Meeting, 68th, Ottawa, Canada, Apr. 23-28, 1989) ONERA, TP no. 1989-88, 1989, 14 p. refs  
(ONERA, TP NO. 1989-88)

The influence of protective coatings on the mechanical properties of superalloys employed in hot sections of gas turbine engines is investigated. The most used coatings are aluminide-based such as MCrAlY overlays and zirconia-based thermal barrier coatings, which may affect the mechanical properties of the superalloy substrates in several ways. Interdiffusion phenomena taking place between coating and substrate at high temperature during service may decrease the load bearing section of the superalloy and, as a consequence, may degrade its creep lifetime. Examples of possible effects of coating/substrate interdiffusion on the creep life of single crystal CMSX2 (no effect) and in the case of a directionally solidified eutectics superalloy (significant degradation) are considered. In the long run, the presence of a coating can enhance the creep life of a substrate due to its protective effect against high temperature corrosion. After considering different factors which can affect the mechanical behavior of the coated systems, a review of recent experimental results is presented. C.E.

**A90-11539****AN OXIDATION FATIGUE INTERACTION DAMAGE MODEL FOR THERMAL FATIGUE CRACK GROWTH**

F. REZAI-ARIA and L. REMY (Paris, Ecole Nationale Supérieure des Mines, Evry, France) Engineering Fracture Mechanics (ISSN 0013-7944), vol. 34, no. 2, 1989, p. 283-294. refs  
Copyright

An oxidation fatigue damage model is proposed to account for crack growth in MAR-M509 superalloy under conditions of isothermal fatigue at high temperature and thermal fatigue. A local stress approach is used in the model to describe the superposition of fatigue and monotonic fracture in a volume element of 100 microns in size ahead of the crack tip at high crack growth rates. The model accounts for the interaction between oxidation and fatigue and includes mechanical parameters fitted to isothermal experiments. It is shown that the model predicts the low-cycle fatigue life to initiate a 0.3-mm-deep crack at 900 C, within a factor of three, for a wide range of testing conditions. V.L.

**A90-11575****TOUGH(ER) ALUMINUM-LITHIUM ALLOYS**

DONALD WEBSTER (Advanced Material Development, Saratoga, CA) and CLIVE G. BENNETT (Comalco Aluminum, Ltd., Melbourne, Australia) Advanced Materials and Processes (ISSN 0882-7958), vol. 136, Oct. 1989, p. 49-52, 54.  
Copyright

Consideration is given to the high impact resistance, of the Al-Li alloys XT 110, 120, 130, and 140. These alloys also have improved short-transverse (L-S notch) fracture toughness and stress-corrosion cracking resistance, compared with commercial Al-Li alloys. The Charpy impact toughness (L-T notch), secondary-hardening behavior, stress-corrosion cracking resistance in the short-transverse direction, and weldability of these alloys are examined. In addition, consideration is given to the market

potential of high-toughness Al-Li alloys for aerospace applications. R.B.

**A90-12514#****COMBUSTION CHARACTERISTICS OF A BORON-FUELED SFRJ WITH AFT-BURNER**

B. NATAN and A. GANY (Technion - Israel Institute of Technology, Haifa) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 140-148. refs  
Copyright

The research deals with a theoretical evaluation of the concept of using an after-burner in the SFRJ motor, where bypass air is added, as a means of enhancing combustion efficiencies of boron containing fuels. The model is solved numerically. A parametric investigation examines the effect of pressure, air mass flux and equivalence ratio. The results reveal that good boron combustion efficiencies and high temperatures can be obtained at optimal conditions. Author

**A90-12534#****MATERIAL REQUIREMENTS FOR FUTURE AEROENGINES**

G. E. KIRK (Rolls-Royce, PLC, Derby, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 335-341.  
Copyright

Future engine requirements are discussed as well as the status of major candidate materials and the problems that need to be solved before these materials can be successfully incorporated. In a discussion of future propulsion system requirements, consideration is given to future civil engines, future military engines, and future small engines. It is noted that new material systems are required to secure the benefits of ultrahigh-bypass-ratio engines for civil applications at acceptable weight and cost. K.K.

**A90-12535#****IMI 834 - A NEW HIGH TEMPERATURE CAPABILITY TITANIUM ALLOY FOR ENGINE USE**

D. F. NEAL (IMI Titanium, Ltd., Research Dept., Birmingham, England) and M. J. WEAVER (Royal Aerospace Establishment, Propulsion Dept., Farnborough, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 342-348. Research supported by the Ministry of Defence and Department of Trade and Industry. refs  
Copyright

A new weldable titanium alloy known as IMI 834 which offers approximately a 10 percent improvement in temperature, strength, and fatigue performance over such alloys as IMI 829 is described. It is designed for disk and blade applications in gas turbine compressors. Optimization of the alloy base and the addition of carbon improved the strength across the usable temperature range and permitted the use of a fine alpha/beta microstructure as well as stress-relief annealing at about 700 C. K.K.

**A90-12538#****PROPERTIES AND CHARACTERISATION OF NOVEL THERMAL BARRIER SYSTEMS FOR GAS TURBINES**

J. E. RESTALL (Royal Aerospace Establishment, Farnborough, England) and K. T. SCOTT (U.K. Atomic Energy Authority, Harwell Laboratory, Didcot, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 365-376. refs  
Copyright

This paper describes the preparation, by sol-gel techniques, of homogeneous zirconia alloy powders suitable for plasma spraying. Thermal and physical properties of coatings produced from them were measured and compared with those of some commercial materials. Coatings of 7 wt pct Y2O3-ZrO2 were found to have

the most promising properties for use as thermal barriers. These include the highest thermal expansion, lowest thermal conductivity, and greatest strength consistent with a fine microstructure which was identified as single-phase nontransformable tetragonal, and unaffected by long exposure at temperatures up to 1100 C. However, strengths could be altered by changing the plasma gas and mode of spraying. Coatings containing greater than 6 wt pct Y<sub>2</sub>O<sub>3</sub> outperformed the other ceramics in laboratory evaluation of their performance as thermal barriers. Failure in magnesia composites was primarily within the ceramic, but at the higher temperatures experienced by the Y<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub> materials, oxidation of the bond and substrate played a substantial role. Author

#### **A90-12539#**

#### **EXTENDING THE OVERHAUL INTERVAL FOR GAS TURBINE ENGINES THROUGH THE USE OF ALTERNATIVE COATINGS ON FIRST STAGE BLADES**

J. L. COCKING, G. R. JOHNSTON, P. G. RICHARDS, and J. MARGERIDIS (Defence Science and Technology Organisation, Materials Research Laboratory, Melbourne, Australia) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 377-387. refs  
Copyright

The paper describes trials of alternative protective coatings which have been conducted on the first stage blades in a number of operational gas turbine engines. The engines were used in a long-range maritime patrol aircraft, a fighter aircraft whose operating profile includes low-level surface terrain following, and a helicopter whose operating profile includes hovering over the ocean. The performance of a range of coatings after about 1000 h of engine operation is described and compared. K.K.

#### **A90-12602#**

#### **ATOMIZATION OF SYNTHETIC JET FUEL**

H. V. HATTINGH, B. J. VAN DER WESTHUIZEN, and J. E. VAN NIEKERK (Stellenbosch, University, Republic of South Africa) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 963-970. refs  
Copyright

Jet A-1 and SASOL synthetic jet fuels were tested in an airblast atomizer to ascertain mean drop sizes in conditions which ranged over wide variations in air pressure, air temperatures, atomizing air velocity, and liquid and air flow-rates. Attention was given to the effect of air pressure and temperature on the initial atomization, as measured at a distance of 25 mm downstream of the atomizer's prefilmer lip. The results obtained indicate improved atomization with increasing air density, increasing atomizing velocity, and increasing air/fuel ratio; in addition, the lower density and surface tension of the SASOL jet fuel, by comparison with those of Jet A-1, were found to have a beneficial effect on atomization. O.C.

**N90-10184\*#** General Electric Co., Cincinnati, OH. Aircraft Engine Business Group.

#### **REVOLUTIONARY OPPORTUNITIES FOR MATERIALS AND STRUCTURES STUDY**

F. A. SCHWEIGER Feb. 1987 169 p  
(Contract NAS3-24622)

(NASA-CR-179642; NAS 1.26:179642) Avail: NTIS HC A08/MF A01 CSCL 11/4

The revolutionary opportunities for materials and structures study was performed to provide Government and Industry focus for advanced materials technology. Both subsonic and supersonic engine studies and aircraft fuel burn and DOC evaluation are examined. Year 2010 goal materials were used in the advanced engine studies. These goal materials and improved component aero yielded subsonic fuel burn and DOC improvements of 13.4 percent and 5 percent, respectively and supersonic fuel burn and DOC improvements of 21.5 percent and 18 percent, respectively. Conclusions are that the supersonic study engine yielded fuel burn

and DOC improvements well beyond the program goals; therefore, it is appropriate that advanced material programs be considered.

Author

**N90-10186\*#** Boeing Aerospace Co., Seattle, WA.

#### **DEVELOPMENT OF PRESSURE CONTAINMENT AND DAMAGE TOLERANCE TECHNOLOGY FOR COMPOSITE FUSELAGE STRUCTURES IN LARGE TRANSPORT AIRCRAFT**

P. J. SMITH, L. W. THOMSON, and R. D. WILSON Washington Aug. 1986 187 p

(Contract NAS1-17740)

(NASA-CR-3996; NAS 1.26:3996) Avail: NTIS HC A09/MF A01 CSCL 11/4

NASA sponsored composites research and development programs were set in place to develop the critical engineering technologies in large transport aircraft structures. This NASA-Boeing program focused on the critical issues of damage tolerance and pressure containment generic to the fuselage structure of large pressurized aircraft. Skin-stringer and honeycomb sandwich composite fuselage shell designs were evaluated to resolve these issues. Analyses were developed to model the structural response of the fuselage shell designs, and a development test program evaluated the selected design configurations to appropriate load conditions. Author

**N90-10187\*#** McDonnell-Douglas Corp., Long Beach, CA.

#### **LAMINAR FLOW CONTROL PERFORATED WING PANEL DEVELOPMENT**

J. E. FISCHLER et al. Oct. 1986 237 p

(Contract NAS1-17506)

(NASA-CR-178166; NAS 1.26:178166) Avail: NTIS HC A11/MF A01 CSCL 11/4

Many structural concepts for a wing leading edge laminar flow control hybrid panel were analytically investigated. After many small, medium, and large tests, the selected design was verified. New analytic methods were developed to combine porous titanium sheet bonded to a substructure of fiberglass and carbon/epoxy cloth. At -65 and +160 F test conditions, the critical bond of the porous titanium to the composite failed at lower than anticipated test loads. New cure cycles, design improvements, and test improvements significantly improved the strength and reduced the deflections from thermal and lateral loadings. The wave tolerance limits for turbulence were not exceeded. Consideration of the beam column midbay deflections from the combinations of the axial and lateral loadings and thermal bowing at -65 F, room temperature, and +160 F were included. Many lap shear tests were performed at several cure cycles. Results indicate that sufficient verification was obtained to fabricate a demonstration vehicle. Author

**N90-10191#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.

#### **COMBUSTION INSTABILITIES IN LIQUID-FUELLED PROPULSION SYSTEMS**

Apr. 1989 306 p In ENGLISH and FRENCH Meeting held in Bath, England, 6-7 Oct. 1988

(AGARD-CP-450; ISBN-92-835-0503-4) Copyright Avail: NTIS HC A14/MF A01

The Specialists' Meeting was arranged in the following sessions: Keynote/Overview; Turbine Engine Development Experience; Rocket and Ramjet Development Experience; and Theoretical Modeling and Experimental Methods and Results. The technical evaluation report is included at the beginning of the proceedings. Questions and answers of the discussions follow each paper.

**N90-10192#** California Inst. of Tech., Pasadena.

#### **COMBUSTION INSTABILITIES IN LIQUID-FUELED PROPULSION SYSTEMS: AN OVERVIEW**

F. E. C. CULICK In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 73 p Apr. 1989 Sponsored in part by California Inst. of Technology; Navy; AF; and Hersh Acoustical Engineering

Copyright Avail: NTIS HC A14/MF A01

## 11 CHEMISTRY AND MATERIALS

Combustion of reactants in a confined volume favors excitation of unsteady motions over a broad range of frequencies. A relatively small conversion of the energy released will produce both random fluctuations or noise, and, under many circumstances, organized oscillations generically called combustion instabilities. Owing to the high energy densities and low losses in combustion chambers designed for propulsion systems, the likelihood of combustion instabilities is high. The accompanying heat transfer to exposed surfaces, and structural vibrations are often unacceptable, causing failure in extreme cases. Combustion instabilities are briefly reviewed in liquid-fueled propulsion systems; rockets, ramjets, and thrust augmentors - with emphasis on work accomplished during the past decade. To provide a common framework for discussing the wide range of works, a theory of two-phase flow is reviewed as the basis for an approximate analysis of combustion instabilities. The analysis is directed primarily to treatment of linear stability; it is sufficiently general to accommodate all processes occurring in actual systems. A new result was obtained for an extended form of Rayleigh's criterion and its relation to the growth constant for unstable waves. The chief mechanisms for combustion instabilities in liquid-fueled systems are reviewed, followed by a summary of the common methods of analysis and applications to the three classes of propulsion systems. Control of instabilities by passive and active means is examined briefly. Author

**N90-10193#** Pratt and Whitney Aircraft, West Palm Beach, FL. Government Engine Business.

### **COMBUSTOR INFLUENCE ON FIGHTER ENGINE OPERABILITY**

THOMAS L. DUBELL and ANTHONY J. CIFONE (Naval Air Propulsion Test Center, Trenton, NJ.) In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 5 p Apr. 1989 Copyright Avail: NTIS HC A14/MF A01

An aspect of combustion instability that is generally unrecognized, but which has a critical influence on aircraft gas turbine engine operability is discussed. The basic lean combustion limit (static stability) of a combustor, when coupled with engine system dynamics, can result in the inability of an engine to recover from a compressor stall. This is a most serious event for a tactical fighter/attack aircraft engaged in air combat. The coupling of combustor static stability characteristics with engine system dynamics is reviewed, a hypothesis presented, solution approaches suggested and plans to address this challenge discussed. Author

**N90-10194#** Rolls-Royce Ltd., Bristol (England).

### **CHARACTERISTICS OF COMBUSTION DRIVEN PRESSURE OSCILLATIONS IN ADVANCED TURBO-FAN ENGINES WITH AFTERBURNER**

B. E. HENDERSON and J. S. LEWIS In AGARD, Combustion Instabilities in Liquid-Fuelled Propulsion Systems 8 p Apr. 1989 Copyright Avail: NTIS HC A14/MF A01

Development of a high thrust to weight ratio engine requires that the maximum afterburner thrust boost is achieved. The achievement of this thrust boost must be free of potentially damaging pressure oscillations. The characteristics of both low and high frequency combustion driven pressure oscillations associated with the afterburner of an advanced turbo-fan engine are described. These oscillations are related to the geometry and flow conditions of the afterburner and engine. Models of the characteristics have been developed based on experimental and theoretical techniques. It is shown how these were used to ensure unrestricted operation of the afterburner system throughout the required operating range. Author

**N90-10231#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

### **CASTINGS AIRWORTHINESS**

May 1989 137 p In ENGLISH and FRENCH Meeting held in Mierlo, Netherlands, 3-7 Oct. 1988 (AGARD-R-762; ISBN-92-835-0507-7) Copyright Avail: NTIS HC A07/MF A01

The question of whether a casting factor, as such, need still be applied to premium quality castings given the improvements in casting technology obtained in recent years, was addressed.

**N90-10233#** Service Techniques des Programmes Aeronautiques, Paris (France). Responsable des Matériaux Structuraux.

### **CASTING FACTORS IMPOSED BY THE FRENCH REGULATION FOR FOUNDRY CASTINGS USED IN MILITARY AIRCRAFT [LES CASTINGS FACTORS IMPOSES PAR LA REGLEMENTATION FRANCAISE POUR LES PIECES DE FONDERIE UTILISEES DANS LES AVIONS MILITAIRES]**

MICHEL ROBERT In AGARD, Castings Airworthiness 6 p May 1989 In FRENCH

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A table summarizing the casting factors imposed on foundry castings to be used in military aircraft is presented and discussed. The principle control and testing requirements for each of three functional classes -- vital, important, and secondary -- are described. Some comments are made regarding the future evolution of casting factors. Transl. by M.G.

**N90-10234#** Service Techniques des Programmes Aeronautiques, Paris (France).

### **CASTING AIRWORTHINESS JOINT EUROPEAN CIVIL AUTHORITIES VIEW-POINT**

MICHEL SANCHO In AGARD, Castings Airworthiness 6 p May 1989

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After a short introduction on the European regulation, JAR 25 (Joint Airworthiness Requirements), the general certification procedures are described: static, fatigue, damage tolerance, manufacturing. Particular application to casting is discussed, particularly extra factors and damage tolerance evaluation. In conclusion a general overview of civil airworthiness authorities is given. Author

**N90-10235#** Royal Aircraft Establishment, Farnborough (England). Airworthiness Div.

### **ROYAL AEROSPACE ESTABLISHMENT: NO PLACE FOR A CASTINGS FACTOR**

A. W. CARDRICK and C. J. PEEL In AGARD, Castings Airworthiness 3 p May 1989 Presented at the AGARD Workshop on Castings Airworthiness, Mierlo, Netherlands, 5-6 Oct. 1988 Copyright Avail: NTIS HC A07/MF A01

The structural design and airworthiness requirements for U.K. military aircraft are published in DEFSTAN 00-970. Once a cast material (and the associated process) has been approved it is treated like any other material; there is no castings factor. This note outlines acceptable procedures for the certification of advanced castings for use in the primary structure of airplanes and helicopters. Author

**N90-10238#** Messier Fonderie, Arudy (France).

### **THE QUESTION OF THE CASTING FACTOR [LE FACTEUR DE FONDERIE EN QUESTION]**

J. P. MANNANT In AGARD, Castings Airworthiness 2 p May 1989 In FRENCH

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Aeronautical castings regulations such as FAR25 (U.S.), DEFSTAN 00970 (U.K.), and AIR 2004/E (France) have not taken into account the recent progress in casting processes, production management, quality assurance and control, and also in user/factory cooperation. Developments in aeronautical parts casting are described and the presuppositions underlying the introduction of casting factors are critically examined. Transl. by M.G.

**N90-10240#** Getti Speciali S.p.A., Torino (Italy).

### **COMBINED ADVANCED FOUNDRY AND QUALITY CONTROL TECHNIQUES TO ENHANCE RELIABILITY OF CASTINGS FOR THE AEROSPACE INDUSTRY**

G. P. CAPELLO and M. CAROSSO In AGARD, Castings



Airworthiness 10 p May 1989

Copyright Avail: NTIS HC A07/MF A01

Aspects of the technological innovation which can contribute, when fully inserted in the productive process, in improving the reliability of castings for use on aircraft are covered. Considered are: the development of processes and the use of means to ensure the absolute repeatability of the critical items with regard to the metallurgical condition of the castings; (mold filling hydraulics and thermal state of the casting; computer assisted management of specific chills; quality of liquid metal; and quenching conditions); and computerized quality control systems which guarantee systematic control of the qualitative conditions of the castings and non-destructive testing systems ensuring an adequate level of reading the internal soundness at acceptable costs (radioscopy linked to image processing systems and high-resolution equipment).

Author

**N90-10242#** Titan-Aluminum-Feinguss G.m.b.H., Bestwig (Germany, F.R.).

**THIN WALLED CAST HIGH-STRENGTH STRUCTURAL PARTS** CH. LIESNER *In* AGARD, Castings Airworthiness 6 p May 1989

Copyright Avail: NTIS HC A07/MF A01

Production and reproducibility in series of thin-walled high-strength structural parts out of aluminum and titanium alloys produced to the investment casting process are reported. Limits referring to dimensions of parts, wall thicknesses and mechanical properties will be shown on chosen examples. Actions of quality assurance for reproducibility in series are necessary. First of all these include pre-material, melt, casting, ceramic coating, heat treatment. Also the good compatibility of the material combination titanium and CFA will be considered.

Author

**N90-10253#** SRI International Corp., Menlo Park, CA.  
**INFLUENCE OF MICROSTRUCTURE AND MICRODAMAGE PROCESSES ON FRACTURE AT HIGH LOADING RATES** Final Report, 1 Feb. 1986 - 30 Sep. 1988

J. H. GIOVANOLA, R. W. KLOOP, J. W. SIMONS, T. KOBAYASHI, and D. A. SHOCKEY 26 Jun. 1989 48 p

(Contract F49620-86-K-0010)

(AD-A210307; TR-90; AFOSR-89-0992TR) Avail: NTIS HC A03/MF A01 CSCL 11/6

The objectives of this 3 year program were to establish how microstructure and loading rate influence the fracture behavior of Ti-10V-2Fe-3Al, a promising advanced titanium alloy increasingly used in aircraft structural components, and to relate the macroscopic fracture toughness results to microdeformation and microdamage processes with a view toward developing microstructurally based fracture models. Such models are desirable to develop compositions and processing conditions resulting in optimum mechanical properties.

GRA

**N90-10255#** Rockwell International Science Center, Thousand Oaks, CA.

**FATIGUE CRACK INITIATION MECHANICS OF METAL AIRCRAFT STRUCTURES** Final Report, 1 Aug. 1986 - 10 Oct. 1987

W. L. MORRIS, M. R. JAMES, and B. N. COX Aug. 1988 93 p

(Contract N62269-86-C-0261)

(AD-A210567; NADC-89044-60) Avail: NTIS HC A05/MF A01

CSCL 11/6

The understanding of deformation process that control the local stresses and strains at the grain size level in order to formulate a physically based model of crack initiation under spectrum loads was studied. Experimental techniques of high spatial resolution strain measurements developed at the Science Center were used to investigate the mechanical behavior of individual constrained grains in Al 2219-T851. Local mechanical properties and yield criteria were deduced from measurements of the local stress/strain hysteresis loop width. Two stages of flow are identified, each involving different yield locus behavior. Mathematical models of the local grain stiffness and the constrained plastic strain range are presented, and a phenomenological description of slip band

nucleation and hardening are stated as functions of the local plastic strain range. These are then incorporated into a crack growth equation modified for plastic deformation to calculate the cycles required for a microcrack to reach the first subsurface grain boundary when propagating in a region of localized plastic flow. This provides a convenient engineering definition of crack initiation because it avoids the anomalous accelerated crack growth often found within the grain of initiation.

GRA

**N90-10293\*#** Ford Motor Co., Dearborn, MI. Scientific Lab.  
**IMPROVED SILICON CARBIDE FOR ADVANCED HEAT ENGINES** Final Annual Report No. 2, 15 Feb. 1986 - 14 Feb. 1987

THOMAS J. WHALEN Oct. 1987 80 p

(Contract NAS3-24384)

(NASA-CR-180831; NAS 1.26:180831) Avail: NTIS HC A05/MF A01 CSCL 11/3

This is the second annual technical report entitled, Improved Silicon Carbide for Advanced Heat Engines, and includes work performed during the period February 16, 1986 to February 15, 1987. The program is conducted for NASA under contract NAS3-24384. The objective is the development of high strength, high reliability silicon carbide parts with complex shapes suitable for use in advanced heat engines. The fabrication methods used are to be adaptable for mass production of such parts on an economically sound basis. Injection molding is the forming method selected. This objective is to be accomplished in a two-phase program: (1) to achieve a 20 percent improvement in strength and a 100 percent increase in Weibull modulus of the baseline material; and (2) to produce a complex shaped part, a gas turbine rotor, for example, with the improved mechanical properties attained in the first phase. Eight tasks are included in the first phase covering the characterization of the properties of a baseline material, the improvement of those properties and the fabrication of complex shaped parts. Activities during the first contract year concentrated on two of these areas: fabrication and characterization of the baseline material (Task 1) and improvement of material and processes (Task 7). Activities during the second contract year included an MOR bar matrix study to improve mechanical properties (Task 2), materials and process improvements (Task 7), and a Ford-funded task to mold a turbocharger rotor with an improved material (Task 8).

Author

**N90-11184#** Allied-Signal Aerospace Co., Des Plaines, IL. Engineered Materials Research Center.

**PRODUCTION OF JET FUELS FROM COAL-DERIVED LIQUIDS. VOLUME 11: PRODUCTION OF ADVANCED ENDOTHERMIC FUEL BLENDS FROM GREAT PLAINS GASIFICATION PLANT NAPHTHA BY-PRODUCT STREAM** Final Report, Sep. 1987 - Dec. 1988

RUSSELL W. JOHNSON, W. C. ZACKRO, G. CZAJKOWSKI, P. P. SHAH, and A. P. KELLY (UOP, Inc., Des Plaines, IL.) Mar. 1989 130 p

(Contract MIPR-FY1455-86-N0655; DE-AC22-87PC-79810; DA PROJ. 2480)

(AD-A210251; AFWAL-TR-87-2042-VOL-11) Avail: NTIS HC A07/MF A01 CSCL 21/4

The U.S. Air Force has an ongoing program to evaluate various endothermic fuels for cooling aircraft structures. The fuels will provide a heat sink by vaporization (latent heat) and endothermic reactions (dehydrogenation) before use as fuel in aircraft engines. Cycloparaffins hold the most promise for use as endothermic fuels. The U.S. Air Force is also evaluating various feedstock sources of endothermic fuels. The technical feasibility of producing endothermic fuel from the naphtha by-product from Great Plains Gasification Plant in Beulah, North Dakota was evaluated. The capital and operating costs of deriving the fuel from coal naphtha were also estimated.

GRA



## ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

**A90-10138****INFRARED TECHNOLOGY XIV; PROCEEDINGS OF THE MEETING, SAN DIEGO, CA, AUG. 15-17, 1988**

IRVING J. SPIRO, ED. (Aerospace Corp., El Segundo, CA) Meeting sponsored by SPIE, Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings, Volume 972), 1988, 438 p. For individual items see A90-10139 to A90-10172.

(SPIE-972) Copyright

Papers on IR technology are presented, covering topics such as crosstalk in closely-spaced In antimonide detectors, elevated temperature operation of InSb linear arrays, a PtSi IR imaging array, avalanche photodiodes for lidar atmospheric return signal detectors, surface leakage current in CdHgTe photodiodes, the responsivity of Si photodiodes, and spatial nonuniformity correction in a staring sensor. Other topics include a multimodule shortwave IR linear array and scene simulator, a 1-5-micron imaging camera, a HgCdTe hybrid focal plane, a dual multiplexed InSb focal plane array, aerosol effects on jet-engine IR radiation, Landsat thermal imaging, hot spot detection, linear pyroelectric arrays, a low altitude IR earth sensor. Additional subjects include an IR high-speed Fabry-Perot interferometer, IR research in Germany, eye safe lasers, In-doped Si detector arrays, rapid multispectral investigations by a compact CO<sub>2</sub> lidar, an IR radiation model for aircraft and reentry vehicles, target classification by vibration sensing, thermal IR CCDs for space applications, and high-power solar-pumped solid-state lasers. R.B.

**A90-10222****AN ASYMPTOTIC THEORY FOR THE PERIODIC TURBULENT BOUNDARY LAYER IN ZERO MEAN-PRESSURE GRADIENT**

A. N. MENENDEZ (Instituto Nacional de Ciencia y Technica Hidricas, Buenos Aires, Argentina) and B. R. RAMAPRIAN (Washington State University, Pullman) Aeronautical Journal (ISSN 0001-9240), vol. 93, Aug.-Sept. 1989, p. 254-264. refs

(Contract DAAG29-79-G-0017; DAAG29-83-K-0004)

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An asymptotic theory valid for large Reynolds number is developed for describing the oscillatory properties of a turbulent boundary layer in a free stream whose velocity varies harmonically with time around a non-zero mean value. The theory identifies two frequency parameters in terms of which four different regimes of oscillation frequency are defined. Similarity laws are identified for each of these frequency regimes and for the different layers of the periodic boundary layer. The theory seems to bring together the available data on unsteady wall bounded flows into a general framework. Author

**A90-10640#****CALCULATION OF CONFINED SWIRLING FLOWS WITH A SECOND MOMENT CLOSURE**

W. P. JONES (Imperial College of Science and Technology, London, England) and A. PASCAU ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 111, Sept. 1989, p. 248-255. Research supported by the Ministry of Defence Procurement Executive. refs

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A Reynolds stress transport equation model and the k-epsilon turbulence model have been applied to the calculation of a confined, strongly swirling flow. A comparison of the results with measurement shows clearly the superiority of the transport equation model. It reproduces the major features of the flow, including the

strong stabilizing effects of the swirl on the shear stresses, and the calculated axial and circumferential components of mean velocity are in reasonable agreement with measured profiles. The corresponding normal stresses are overpredicted, but previously suggested modifications to the epsilon-equation to account for rotation did not bring any improvement. The k-epsilon model does not contain any mechanism to describe the stabilizing effects of swirling motion, and, as a consequence, it performs poorly; large discrepancies exist between the measured and calculated mean velocity field. Author

**A90-10732****HOLOGRAPHIC INTERFEROMETRIC STUDY OF SHOCK WAVE PROPAGATION**

K. TAKAYAMA, K. ITOH, O. ONODERA, and H. OJIMA (Tohoku University, Sendai, Japan) IN: International Congress on High Speed Photography and Photonics, 18th, Xian, People's Republic of China, Aug. 28-Sept. 2, 1988, Proceedings, Part 1. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 389-396. refs

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A successful application study of shock tube flow holographic interferometry has been conducted at the Institute of High Speed Mechanics of Tohoku University, Japan. A shock wave propagation experiment over a circular cylinder, an elliptical cylinder, and an NACA 0012 airfoil was performed, using a 60 mm x 150 mm shock tube of the Shock Wave Research Center equipped with double exposure holographic interferometry with a 300-mm field of view. An NACA 0012 airfoil with an angle of attack was placed in the transonic shock tube flow for quantitative observation of the whole shock propagation process and starting of a transonic flow. The shock Mach number was 1.7 in air and the local flow Mach number was 0.77. The isopycnics were compared with numerical simulation results and the quantitative data were evaluated from the interferograms; the unsteady drag coefficients of these bodies under shock wave loading could be determined both experimentally and numerically. Good agreement was obtained between the experiment and the numerical simulation. C.E.

**A90-10748****COLOR SCHLIEREN SYSTEM USING SQUARE COLOR FILTER AND ITS APPLICATION TO AEROFOIL TEST IN TRANSONICS**

RUIYI CHEN and ZHOUFANG GE (Zhejiang University, Hangzhou, People's Republic of China) IN: International Congress on High Speed Photography and Photonics, 18th, Xian, People's Republic of China, Aug. 28-Sept. 2, 1988, Proceedings, Part 2. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 845-849.

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This paper describes the principle of the color schlieren technique which uses a piece of square color filter for the source mask and a square hole for the cutoff mask. The relationship between the color of the element on the image and the deflection of the emitting light rays is discussed, and the formulas of the amount and the direction of deflection of the light rays are given. The technique is applied to a test of transonics flow around a NACA 0012 airfoil. The results are compared with the surface pressure measurements made by the sensor. Author

**A90-11041****COMPARISON OF THREE CONCEPTS FOR A LONG STROKE DISPLACEMENT TRANSDUCER**

GERHARD GROSCH (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Fiber optic sensors III; Proceedings of the Meeting, Hamburg, Federal Republic of Germany, Sept. 21, 22, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 82-89. refs

(Contract BMFT-13-AS-0038/3)

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Linear fiber optic long stroke displacement transducers would find many applications in process control, especially because of their immunity to electromagnetic interference, but so far no practical solutions have come up. In order to develop a better

understanding of the underlying problems, a top-down evaluation of published sensor ideas was carried out, followed by an experimental study of some key aspects of three different concepts. The well known problems in qualifying fiber optic sensors for the field were encountered once again. Author

**A90-11042****REVIEW OF FIBER OPTIC METHODS FOR STRAIN MONITORING AND NON-DESTRUCTIVE TESTING**

STAAS J. A. BRUINSMA (Centrale Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek, Technisch Fysische Dienst TNO, Delft, Netherlands) IN: Fiber optic sensors III; Proceedings of the Meeting, Hamburg, Federal Republic of Germany, Sept. 21, 22, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 122-129. refs Copyright

Fiber optic methods for the inspection of the critical components of mechanical structures are reviewed, focusing on the detection of cracks and strain and noncontact ultrasonic inspection. Crack detection using a multimode optical fiber bonded to the surface or integrated within the structural component is discussed. Techniques for strain measurement include strain sensors based on the modulation of transit time, transmitted intensity modulation, and phase and frequency modulation. Also, acoustic emission detection and analysis for the inspection of composite structures is examined. Methods for noncontact ultrasonic inspection of flaws are presented, emphasizing laser generation of ultrasound and the optical detection of ultrasound. R.B.

**A90-11102\*# North Carolina State Univ., Raleigh.****GRID GENERATION AND ADAPTATION FOR THE DIRECT SIMULATION MONTE CARLO METHOD**

DAVID P. OLYNICK, H. A. HASSAN (North Carolina State University, Raleigh), and JAMES N. MOSS (NASA, Langley Research Center, Hampton, VA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 3, Oct. 1989, p. 368-373. Research supported by USAF and U.S. Navy. Previously cited in issue 17, p. 2854, Accession no. A88-43770. refs (Contract NCC1-112; NAGW-1072) Copyright

**A90-11114#****COMPUTATION OF LAMINAR MIXED CONVECTION FLOW IN A CHANNEL WITH WING TYPE BUILT-IN OBSTACLES**

G. BISWAS, N. K. MITRA, and M. FIEBIG (Bochum, Ruhr-Universitaet, Federal Republic of Germany) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 3, Oct. 1989, p. 447-453. Research supported by the Alexander von Humboldt-Stiftung. Previously cited in issue 17, p. 2851, Accession no. A88-43723. refs Copyright

**A90-11136#****SEVERAL PROBLEMS POSED BY AEROTHERMAL CALCULATIONS IN MACHINES [QUELQUES PROBLEMES POSES PAR LES CALCULS D'AEROTHERMIQUE DANS LES MACHINES]**

DENIS DUTOYA (ONERA, Chatillon-sous-Bagneux, France) (SFT and Societe Francaise des Mecaniciens, Journees sur la Mecanique et Thermique dans les Turbomachines, Paris, France, June 27, 28, 1989) ONERA, TP no. 1989-102, 1989, 18 p. In French. (ONERA, TP NO. 1989-102)

Problems encountered in the quantitative prediction of high-temperature aerodynamic flows are discussed, with emphasis placed on problems relating to spatial scale and time scale. It is suggested that the discretization networks employed should be adapted to the configuration under consideration, that special attention be given to the stability of the calculated states, and that the validity of the physical models employed should be verified for each new flow type studied. The MATILDA code is used to solve the Navier-Stokes equations for the example of a diesel engine cylinder. R.R.

**A90-11173#****3D CALCULATIONS OF REACTING FLOWS WITHIN AIRCRAFT ENGINE COMBUSTION CHAMBERS**

F. PIT, H. TICHTINSKY, and F. DUPOIRIEUX (ONERA, Chatillon-sous-Bagneux, France) (International Seminar on Flame Structure, 3rd, Alma-Ata, Kazakh SSR, Sept. 18-22, 1989) ONERA, TP no. 1989-153, 1989, 5 p. refs (ONERA, TP NO. 1989-153)

Some three-dimensional calculations have been worked out in the case of an aircraft engine combustion chamber containing one swirling fuel-air injector and four primary holes. The influence of the grid size and of some parameters of the combustion and turbulence models has been investigated. The combustion efficiency is relatively insensitive to the grid size unlike the maximum wall temperature and depends slightly on the treatment of the k-epsilon equations near the wall. Author

**A90-11410****A MULTICHANNEL WIDE FOV INFRARED RADIOMETRIC SYSTEM**

S. JACOBSON, Z. LISSAK, Y. YOAV, Y. KOMET, and R. DAVIDSON (Israel Aircraft Industries, Ltd., Lod) IN: Meeting on Optical Engineering, 6th, Tel Aviv, Israel, Dec. 19-21, 1988, Proceedings. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 502-509. Copyright

A radiometric system which consists of five IR radiometers with a mutual data acquisition system is described. The system was designed, developed and built at IAI to conduct simultaneous IR signature measurements of a high intensity source at different aspect angles. The requirement to provide a wide FOV radiometric capability led to a technical solution based on the combination of refractive and reflective optics. Each radiometer is equipped with a ZnSe lens, elliptical mirror, mechanical chopper and a thermoelectrically cooled PbSe detector. The chopper is positioned before the entrance aperture and its blades serve as an ambient temperature reference Black Body. The reference temperature is monitored by a temperature transducer. The optical layout of the radiometers and relevant ray tracing examples are demonstrated. The radiometer sensitivity and field of view response data are presented. The data acquisition as well as software capabilities are described. The system is remotely operated. Data on source intensity, at different aspect angles, may be obtained immediately after the test. Author

**A90-11557#****A STUDY OF UNSTEADY ROTOR-STATOR INTERACTIONS**

REDA R. MANKBADI (Cairo University, Egypt) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 111, Oct. 1989, p. 394-400. refs Copyright

The rotor-generated unsteady response of the turbulent flow in a stator is simulated using a simplified situation of the flow between two parallel plates to represent flow between the stator blades; the rotor's effect is represented by moving cylinders of equivalent drag coefficient that produce passing wakes at the entrance of the stator. Results indicate that the wake passing produces an increase in the time-averaged pressure field in the direction of the rotor traverse, resulting in a rotor-induced lift on the stator blades. Within a distance along the stator equal to its height, the rotor's effect on the pressure field of the stator decreases. As the equivalent drag coefficient of the cylinders increases, oscillations in velocity, pressure, and the turbulence energy increase. An increase in the rotor speed increases the initial oscillation in the flow field but causes its rapid decay along the channel. I.S.

**A90-11659****FIBER OPTIC SYSTEMS FOR MOBILE PLATFORMS II; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 6, 7, 1988**

NORRIS E. LEWIS, ED. (Litton Industries, Poly-Scientific Div., Blacksburg, VA) and EMERY L. MOORE, ED. (Litton Industries,

Guidance and Control Systems Div., Woodland Hills, CA) Meeting sponsored by SPIE, Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings, Volume 989), 1989, 220 p. For individual items see A90-11660 to A90-11675. (SPIE-989) Copyright

The papers contained in this volume provide an overview of recent research and development efforts in the fiber optic systems for mobile platforms. The applications discussed include aircraft, shipboard, automotive, and spacecraft, launch, and missile systems. Papers are presented on the performance of linear fiber optic data buses, military applications of fiber optic tethered vehicle technology, fiber optic switches for missile and space environments, and fiber optic data networks and components for space station applications. V.L.

#### A90-11662

##### **DIRECT FREQUENCY MODULATION IN INTERFEROMETRIC SYSTEMS**

DENISE M. FRANCIS and WALTER L. GLOMB, JR. (United Technologies Research Center, East Hartford, CT) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 18-28. refs Copyright

This paper discusses direct frequency modulation of semiconductor lasers with a linear current ramp and its use in optical sensors. The laser diodes evaluated were the Sharp LT015, Mitsubishi 2901, the Hitachi HL8314 and HLP1400. The maximum attainable frequency deviations ranged between 20 to 50 GHz. Chirp rates ranged from 10 to the 13th to 10 to the 15th Hz/sec for modulation amplitudes from 5 to 15 mA and modulation frequencies from 500 Hz to 200 kHz. The upper limit for efficient direct frequency modulation was at 50 KHz. Coherence lengths from less than 1 meter to greater than 5 meters were measured from the devices. Measurements of power level, frequency deviation, and noise predict measurement of distances up to 13 meters with 0.01 cm accuracy, using conventional channel substrate planar AlGaAs lasers. Author

#### A90-11665

##### **THE PERFORMANCE OF LINEAR FIBER OPTIC DATA BUSES**

MICHAEL B. MILLER and NORRIS E. LEWIS (Litton Industries, Poly-Scientific Div., Blacksburg, VA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 43-48. Copyright

This paper presents measured performance data for linear fiber optic data bus configurations. Requirements and measurements for the individual data bus components including fiber optic couplers, transmitters, and receivers are given, including environmental performance. Demonstrated performance parameters for several linear data bus configurations with up to 69 nodes and data rates up to 50 megabits per second are presented. Author

**A90-11702\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

##### **FIBER OPTICS FOR ADVANCED AIRCRAFT**

ROBERT J. BAUMBICK (NASA, Lewis Research Center, Cleveland, OH) IN: Fiber optic and laser sensors VI; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 5-11. Previously announced in STAR as N88-26328. Copyright

The increased use of composites makes the digital control more susceptible to electromagnetic effects. In order to provide the protection to the digital control additional shielding will be required as well as protective circuitry for the electronics. This results in increased weight and reduced reliability. The advantages that fiber optic technology provides for advanced aircraft applications is recognized. The use of optical signals to carry information between the aircraft and the control module provides

immunity from contamination by electromagnetic sources as well as other important benefits such as reduced weight and volume resulting from the elimination of the shielding and the replacement of metal conductors with low weight glass fibers. In 1975 NASA began work to develop passive optical sensors for use with fiber optics in aircraft control systems. The problem now is to choose the best optical sensor concepts and evaluate them for use. In 1985 NASA and DOD entered into a joint program, Fiber Optic Control System Integration (FOCSI), to look at optical technology specifically for use in advanced aircraft systems. The results of this program are discussed. The conclusion of the study indicated that the use of fiber optic technology in advanced aircraft systems is feasible and desirable. The study pointed to a lack of available sensors from vendors capable of operating in the adverse environments of advanced aircraft. Author

#### A90-11703

##### **APPLICATIONS OF FIBER OPTIC SENSORS IN ADVANCED ENGINE CONTROLS**

EDWARD F. NITKA, II (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) IN: Fiber optic and laser sensors VI; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 12-19. (Contract F33615-86-C-2668) Copyright

Measured parameters, operating ranges, accuracy requirements, environmental constraints, and speed of response of fiber optic sensors are identified for three categories of engines. The three engine categories are: (1) current turbojet, turbofan, and turboprop engines; (2) next generation and turbofan engines to be built in the 1990s; and (3) advanced supersonic/hypersonic engines represented by ramjet, scramjet, and air-turbo-ramjet concepts. The key development and test efforts in engine control applications of fiber optic sensors are discussed. V.L.

#### A90-11704

##### **FIBER OPTIC SENSORS FOR AIRCRAFT**

GLEN E. MILLER (Boeing Electronics High Technology Center, Seattle, WA) IN: Fiber optic and laser sensors VI; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 20-25. Copyright

Some of the more common classes of fiber optic sensors are reviewed. In particular, the characteristics of three broad classes of fiber optic sensors (hybrid, self-generating, and electrically-passive/optically-active) are compared with those of the conventional electrical sensor. Examples of solved and unsolved problems that may have prevented the immediate acceptance of the new technology by the aircraft industries are examined. V.L.

#### A90-11804#

##### **NUMERICAL STUDY OF CENTRIFUGAL IMPELLER RESPONSE TO AN OUTLET PRESSURE DISTORTION**

M. TH. SIDERIS (Institut von Karman de Dynamique des Fluides, Rhode-Saint-Genese, Belgium) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 689-706. refs

A numerical approach to compute the response of a centrifugal impeller to a downstream circumferential static pressure distortion is presented. The two-dimensional, unsteady Euler equations are solved on a blade-to-blade streamsurface by means of a time-marching technique. The computational domain in the physical plane is limited to a single channel. Due to the fact that periodicity of the flow exists only every 360 deg, time lagged periodic boundary conditions have been used. Numerical results are compared to experimental data. Author

**A90-11950#****DEVELOPMENT OF NEW SEGMENT CARBON SEAL FOR USE AT LOW SEALING PRESSURE REGION FJR710/600S TURBO FAN ENGINE**

KUNIYASU YAMANAKA, TAKAHARU OHNO, and HIDEO KOBAYASHI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, July 1989, p. 278-283. In Japanese, with abstract in English.

In an attempt to obtain better oil sealing performance, a new carbon segment type seal was developed. This new seal has helical grooves at the rubbing surface and it allows the oil penetrating the rubbing surface to return to the bearing oil chamber even at low sealing pressure. K.K.

**A90-12190****MULTIPLE CHANNEL FREQUENCY DEMODULATOR**

G. SCHROEDER and J. LEHMANN (Fairchild Weston Systems, Inc., Sarasota, FL) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 211-226. refs

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The design and capabilities of a multiple-channel frequency demodulator (discriminator) are presented. A single unit provides simultaneous precision demodulation of up to 24 FDM FM channels. Digital TDM outputs are provided for acceptance by modern telemetry computer systems. Author

**A90-12479****VORTEX-FLOW COMPRESSORS [VIKHREVEY KOMPRESSORY]**

IGOR' M. VIRSHUBSKII, FELIKS S. REKSTIN, and ANATOLII IA. SHKVAR Leningrad, Izdatel'stvo Mashinostroenie, 1988, 272 p. In Russian. refs

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The fundamentals of the theory of vortex-flow compressors are presented, and the existing hypotheses of the working cycle are examined. The effect of the principal similarity criteria on the efficiency of vortex-flow compressors is demonstrated; the limits of self-similarity are determined using these criteria. Expressions are proposed for calculating the performance characteristics of compressors for gases of different physical properties and different Mach and Reynolds numbers. Particular attention is given to the optimization of the geometry of the flow path and general design of vortex-flow compressors. Examples of typical designs and proven engineering calculation methods are presented. V.L.

**A90-12561#****INVESTIGATION OF THE MIXING OF PARALLEL SUPERSONIC STREAMS**

H. E. GILREATH and G. A. SULLINS (Johns Hopkins University, Laurel, MD) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 585-595. refs

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Results are presented on a study of the stability, structure, and growth of the shear layer formed between two coflowing supersonic streams, representing contributions from three different laboratories. Numerical simulations showed that the overall stability of flows in this category may be profoundly affected by both the flow geometry and initial conditions. Turbulence measurements from a supersonic slot injection flow field in a supersonic wind tunnel showed that, at the conditions in which the 'missing physics' associated with pressure-strain correlations is of little concern, the k-epsilon model produces a reasonable prediction of experimental data. The mean flow development appeared to be relatively insensitive to turbulence initial conditions. Diagrams of the test facilities used in the study are presented together with experimentally obtained velocity profiles. I.S.

**A90-12579#****UNBALANCE RESPONSE STUDIES ON A MODEL ROTOR SUPPORTED ON UNCENTRALISED SQUEEZE FILM DAMPERS AND THE DEVELOPMENT EXPERIENCE OF A JET ENGINE**

S. C. KAUSHAL, K. G. MARATHE, A. V. BALASANKARAN, and SREELAL SREEDHAR (Gas Turbine Research Establishment, Bangalore, India) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 757-764. refs

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A simplified experimental approach consisting of parametric study to optimize damper design followed by the unbalance response study on a modeled rotor has been suggested to develop uncentralized squeeze film damper configuration for a gas turbine engine. The amplitude dependent support stiffness using quasi-analytical approach based on short bearing theory and the constant damping have been used to predict the rotor unbalance response and reasonable agreement with the experimental trend has been observed only at low eccentricities and lower unbalance conditions. Author

**A90-12606\*\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**ADVANCED COMPUTATIONAL TECHNIQUES FOR HYPERSONIC PROPULSION**

LOUIS A. POVINELLI (NASA, Lewis Research Center, Cleveland, OH) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 993-1008. Previously announced in STAR as N89-23809. refs

Computational Fluid Dynamics (CFD) has played a major role in the resurgence of hypersonic flight, on the premise that numerical methods will allow performance of simulations at conditions for which no ground test capability exists. Validation of CFD methods is being established using the experimental data base available, which is below Mach 8. It is important, however, to realize the limitations involved in the extrapolation process as well as the deficiencies that exist in numerical methods at the present time. Current features of CFD codes are examined for application to propulsion system components. The shortcomings in simulation and modeling are identified and discussed. Author

**A90-12618#****THE DEVELOPMENT OF A HIGH RESPONSE AERODYNAMIC WEDGE PROBE AND USE ON A HIGH-SPEED RESEARCH COMPRESSOR**

S. C. P. COOK (Rolls-Royce, PLC, Derby, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1113-1125. Research supported by Rolls-Royce, PLC and Ministry of Defence. refs

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A high-response aerodynamic wedge probe has been developed for performance testing of high-speed, axial-flow research compressors and fans. The miniature probe incorporates flush-mounted high response silicon piezoresistive pressure transducers, with both a dynamic and steady state measurement capability. New information on wedge probe aerodynamic sensitivity is given, along with details of an important reduction algorithm facilitating successful use on dynamic data. An electronic compensation scheme was used to overcome the inherent temperature sensitivity of the transducers. Previously unreported transducer output nonlinearities were revealed. The 30 degree included angle wedge probe has a frequency response in excess of 100 kHz. Time resolved rotor wakes were measured with the wedge probe applied to the 9-kHz high-speed blade of an axial-flow research compressor. Compared with rotating wake data obtained using a crossed hot wire anemometer probe, the rotor wakes were found to be highly unsteady in terms of both amplitude and spatial friction. C.E.

**A90-12626#****CFD PREDICTIONS OF LOBED MIXER FLOWFIELDS**

P. KOUTMOS and J. J. MCGUIRK (Imperial College of Science, Technology and Medicine, London, England) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1187-1199. refs

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A finite volume procedure capable of calculating the flow and heat transfer within complex three-dimensional geometries has been used to compute the aerodynamic flow and associated temperature mixing within a turbofan lobed mixer nozzle. The calculation of the downstream mixing duct is coupled with the lobe flow predictions to allow for the prediction of the complete lobed mixer/nozzle system as described and presented in Koutmos and McGuirk (1989). In the present work, a variety of numerical parametric studies are discussed to investigate global performance variations brought about by changes in mixer inflow conditions. Attention is focused on the prediction of overall performance parameters such as mixing effectiveness and total pressure losses which are essential for the evaluation and optimization of internal lobed mixer configurations. C.E.

**A90-12628#****NON-ITERATIVE ANALYTICAL METHODS FOR OFF-DESIGN TURBOFAN CALCULATIONS WITH OR WITHOUT MIXED-FLOWS**

J. L. MONTANES (Escuela Tecnica Superior de Ingenieros Aeronauticos; Sener Ingenieria y Sistemas, S.A., Madrid, Spain) IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1207-1213. refs

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An analytical method to obtain turbofan off-design behavior is presented. Based on general features of turbofan working characteristics (maximum flow capacities in turbines and nozzles), simple explicit equations are obtained to calculate off-design characteristics of both mixed and unmixed turbofans. The assumptions used are valid to obtain preliminary results in feasibility studies where a large number of parameters are involved. The analytical method makes it possible to assess the influence of parameters on general trends. Comparison with detailed numerical calculations are also presented to validate the proposed analytical method. Author

**A90-12630#****THE REMOTE SENSING OF TEMPERATURE IN GAS TURBINE ENGINE COMPONENTS USING EPITHERMAL NEUTRONS**

P. H. FOWLER, A. M. GAY (Bristol, University, England), M. J. ALLEN, K. MCNICHOLAS, J. D. ROGERS (Rolls-Royce, PLC, Advanced Projects Dept., Bristol, England) et al. IN: International Symposium on Air Breathing Engines, 9th, Athens, Greece, Sept. 3-8, 1989, Proceedings. Volume 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1223-1227. Research supported by SERC.

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Epithermal neutrons may be used to measure temperature noninvasively inside operating machinery. The Doppler broadening of neutron resonances in elements such as tantalum, hafnium, rhenium, and tungsten has been shown to give temperature information to an accuracy of better than  $\pm 0.4$  K in 1000 K. Author

**A90-12844#****VIBRATION ANALYSIS OF COMPOSITE TURBOPROPELLERS USING A NONLINEAR BEAM-TYPE FINITE-ELEMENT APPROACH**

J. B. KOSMATKA and P. P. FRIEDMANN (California, University, Los Angeles) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1606-1614. refs

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An analytical model for determining the free vibration characteristics of advance composite turbopropellers (prop-fans) is presented. The blade is modeled using a number of straight beam-type finite elements, where the elastic axis of each element is a piecewise straight representation of the curved line of shear centers of the swept blade. The finite-element model is obtained from Hamilton's principle, with allowances for generally anisotropic material behavior, arbitrary cross-sectional properties, large pretwist angles, out-of-plane cross-section warping, and geometrically nonlinear behavior, based on moderate-deflection theory. The natural frequencies and mode shapes of the rotating blade are calculated assuming linear perturbations about the nonlinear static equilibrium position of the blade. This model is sufficiently general to analyze other advanced composite aerospace structures. Numerical results are presented to illustrate the versatility of the method by applying it to (1) a conventional propeller (TRW-Hartzell 101/16) and (2) a highly swept and pretwisted isotropic turbopropeller (NASA SR-3). Excellent agreement with experimental test results is obtained for the lower modes of both the conventional propeller and the advanced turbopropeller. Author

**A90-12999****WILDHABER-NOVIKOV CIRCULAR ARC GEARS - SOME PROPERTIES OF RELEVANCE TO THEIR DESIGN**

A. DYSON, H. P. EVANS, and R. W. SNIDLE (University College, Cardiff, Wales) Royal Society (London), Proceedings, Series A - Mathematical and Physical Sciences (ISSN 0080-4630), vol. 425, no. 1869, Oct. 9, 1989, p. 341-363. Research supported by SERC.

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This paper follows an earlier one by Dyson et al. in which a rigorous basic theory of the geometry and kinematics of Wildhaber-Novikov circular arc gears was developed. It was then applied to a pair of helicopter rotor final drive gears, operating in the conditions for which they were designed. The present paper extends this treatment by considering the effect of some variations on the same basic design, and of operating in conditions different from those for which the gears were designed. Aspects considered include the sensitivity of the pressure angle to changes in centers distance, the compromise between this sensitivity and reduction in contact stress, the relation between pressure angle and centers distance over the entire range theoretically possible, the avoidance of interference, the extent of the contact area in terms of position on the teeth, backlash and internal gears. Author

**A90-13011****DESIGN AND APPLICATION OF A FINITE ELEMENT PACKAGE FOR MODELLING TURBOMACHINERY VIBRATIONS**

R. FIROOZIAN and R. STANWAY (Liverpool, University, England) Journal of Sound and Vibration (ISSN 0022-460X), vol. 134, Oct. 8, 1989, p. 115-137. Research supported by SERC. refs

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The purpose of this paper is to review the modeling of lateral vibrations in turbomachinery and to justify and describe the systematic development of a software package based upon finite element techniques. The package is capable of providing stability analysis, steady state and transient responses which were required in connection with a study to compare vibration control techniques. Emphasis is placed on user-friendliness and careful validation by comparison with available results from rotor-bearing systems of gradually increasing complexity. A series of examples is included to illustrate the application of the package and compare its performance with other well known methods. Computational requirements (for an IBM 3083 machine) are discussed in some detail. Author

**A90-13091\*** Texas A&M Univ., College Station.**AUGMENTED HEAT TRANSFER IN RECTANGULAR CHANNELS OF NARROW ASPECT RATIOS WITH RIB TURBULATORS**

J. C. HAN, S. OU, J. S. PARK, and C. K. LEI (Texas A & M University, College Station) International Journal of Heat and

Mass Transfer (ISSN 0017-9310), vol. 32, Sept. 1989, p. 1619-1630. refs  
(Contract NAG3-311; NAS3-24227)  
Copyright

The effects of the rib angle-of-attack on the distributions of the local heat transfer coefficient and on the friction factors in short rectangular channels of narrow aspect ratios with a pair of opposite rib-roughened walls are determined for Reynolds numbers from 10,000 to 60,000. The channel width-to-height ratios are 2/4 and 1/4; the corresponding rib angles-of-attack are 90, 60, 45, and 30 deg, respectively. The results indicate that the narrow-aspect-ratio channels give better heat transfer performance than the wide-aspect-ratio channels for a constant pumping power. Semiempirical friction and heat transfer correlations are obtained. The results can be used in the design of turbine cooling channels of narrow aspect ratios. Author

**N90-10351#** Westinghouse Electric Corp., Lima, OH.  
**HIGH TEMPERATURE VSCF (VARIABLE SPEED CONSTANT FREQUENCY) GENERATOR SYSTEM Final Report, 16 Sep. 1985 - 30 Jun. 1988**

THOMAS ALLEN MAPHET, JACK LEE MCCABRIA, CARROLL CHARLES KOUBA, JAMES THOMAS MITCHELL, and JAMES ROBERT KWIECINSKI Apr. 1989 66 p  
(Contract F33615-85-C-2551; AF PROJ. 3145)  
(AD-A210823; AFWAL-TR-88-2144) Avail: NTIS HC A04/MF A01 CSCL 10/2

The high temperature VSCF generator program was designed to develop a generating system capable of withstanding constantly high oil-in temperatures of 200 C in an ambient environment of 200 C. This is a requirement due to anticipated new fighter aircraft designs that will not be capable of cooling the oil to 100 C as in today's designs due to size restrictions of the heat exchanger and/or extended operation of the aircraft at supersonic speeds. The generator uses composite material to withstand the constant use of 200 C inlet oil. GRA

**N90-10356#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.  
**FLUID DYNAMICS OF THREE-DIMENSIONAL TURBULENT SHEAR FLOWS AND TRANSITION**

Apr. 1989 415 p In ENGLISH and FRENCH Symposium held in Cesme, Turkey, 3-6 Oct. 1988  
(AGARD-CP-438; ISBN-92-835-0502-6) Copyright Avail: NTIS HC A18/MF A01

The trends and achievements of current research activities in three dimensional turbulent shear flows and transitions were determined and the problems on which future research should be focussed were highlighted. Seven sessions devoted to the topic of transition are included, and these sessions well represented the current state of the art. The characteristics of three dimensional turbulent shear flows were dealt with in five sessions, a reflection of the fact that here much more experimental work is needed, and the effort devoted to this difficult topic has not yet reached the level required.

**N90-10357\*#** Arizona State Univ., Tempe. Mechanical and Aerospace Engineering.

**STABILITY AND TRANSITION OF THREE-DIMENSIONAL BOUNDARY LAYERS**

WILLIAM S. SARIC and HELEN L. REED In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 20 p Apr. 1989  
(Contract NAG1-280; NAG1-402; NAG1-731)

Copyright Avail: NTIS HC A18/MF A01 CSCL 20/4

The most recent efforts on the stability and transition of three-dimensional flows are reviewed. These include flows over swept wings, rotating disks, and attachment lines. The generic similarities of their stability behavior is discussed. It is shown that the breakdown process is very complex, often leading to contradictory results. Particular attention is paid to opposing observations of stationary and traveling wave distances. Author

**N90-10358#** Royal Aircraft Establishment, Farnborough (England).

**EXPERIMENTAL INVESTIGATION OF ATTACHMENT-LINE TRANSITION IN LOW-SPEED, HIGH-LIFT WIND-TUNNEL TESTING**

B. C. HARDY In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 17 p Apr. 1989  
Copyright Avail: NTIS HC A18/MF A01

The state of the attachment-line boundary layer on two typical, low-speed, high-lift wind-tunnel models was investigated experimentally. Transition was observed on both models within the Reynolds number range of the Royal Aerospace Establishment 5 meter, low-speed, pressurized Wind Tunnel, but significant differences were found from the behavior previously observed using infinite swept and high-speed wing configurations. An adverse Reynolds number effect on maximum lift, which correlated quite well with the onset of attachment-line transition, was found for one of the models. No such effect was found with the other model but in this case laminarization following transition at the attachment line was observed and is suggested as a probable reason for the absence of any scale effect on the forces within the Reynolds number range of both tests. It is concluded that attachment-line transition and laminarization can both contribute to scale effect in low-speed, high-lift testing and that, for many aircraft, accurate simulation of the full-scale behavior in conventional wind tunnel is unlikely. It is suggested that further work is required to establish whether these effects are likely to give rise to significant discrepancies between high-lift performance measured in the tunnel and in flight. Author

**N90-10362#** Office National d'Etudes et de Recherches Aérospatiales, Toulouse (France).

**EXPERIMENTAL STUDY OF TRANSITION AND LEADING EDGE CONTAMINATION ON SWEEPED WINGS (ETUDE DE LA TRANSITION ET DE LA CONTAMINATION DE BORD D'ATTAQUE SUR AILES EN FLECHE)**

D. ARNAL and J. C. JUILLEN In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 14 p Apr. 1989 In FRENCH; ENGLISH summary  
Copyright Avail: NTIS HC A18/MF A01

The transition mechanisms in an incompressible laminar boundary layer developing on swept wings is investigated experimentally. The transition is detected by using hot films glued on the model. Two series of experiments are presented: in the first one, the sensors are placed along the chord and the instantaneous signals allow us to analyse the problems of streamwise instability, crossflow instability, and leading edge contamination. In the second series of experiments, hot films are glued along the span direction, close to the leading edge. The leading edge contamination is studied in detail and the possibilities of relaminarization are examined. Author

**N90-10366\*#** High Technology Corp., Hampton, VA.

**CURVATURE EFFECTS ON THE STABILITY OF THREE-DIMENSIONAL LAMINAR BOUNDARY LAYERS**

F. S. COLLIER, JR. and MUJEEB R. MALIK In AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 15 p Apr. 1989  
(Contract NAS1-18240)

Copyright Avail: NTIS HC A18/MF A01 CSCL 20/4

The linear stability equations for compressible, three-dimensional laminar boundary layer flow are derived in an orthogonal curvilinear coordinate system. The system of equations is solved using a finite difference scheme in order to study the effects of streamline and surface curvature and compressibility on the stability of the flow past a swept wing. It is known that convex surface curvature can have a stabilizing effect on the laminar boundary layer. Conversely, concave surface curvature can be destabilizing. The magnitude of these effects for swept wings is determined. Results indicate that amplification rates and hence, N-factors, for the flow over the convex upper surface of a swept wing can be reduced by about 15 to 45 percent when curvature effects are included in the linear stability analysis. The results of



the calculations show that concave curvature destabilizes crossflow type disturbances with a significant increase in amplification rate. In addition, comparisons are made with some experimental results on a swept concave-convex surface. Calculated velocity vector plots show good agreement with observed disturbances in the laminar boundary layer over the concave surface. Author

**N90-10368\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**SIMULTANEOUS DETECTION OF SEPARATION AND TRANSITION IN SURFACE SHEAR LAYERS**

SIVA M. MANGALAM (Analytical Services and Materials, Inc., Hampton, VA.), J. P. STACK, and W. G. SEWALL /in AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 10 p Apr. 1989

Copyright Avail: NTIS HC A18/MF A01 CSCL 20/4

Flush-mounted hot-film gages have proved effective in detecting boundary-layer transition and in measuring skin friction but with limited success in detecting laminar separation and reattachment. The development of multielement micro hot-film sensors, and the recent discovery of the phase reversal phenomena associated with low-frequency dynamic shear stress signals across regions of laminar separation and turbulent reattachment, have made it possible to simultaneously and unambiguously detect these surface shear layer characteristics. Experiments were conducted on different airfoils at speeds ranging from low subsonic to transonic speeds to establish the technique for incompressible and compressible flow applications. The multielement dynamic shear stress sensor technique was successfully used to detect laminar separation, turbulent reattachment, as well as, shock induced laminar and turbulent separation. Author

**N90-10377\*** Office National d'Etudes et de Recherches Aeronautiques, Toulouse (France).

**CONTROL AND MODIFICATION OF TURBULENCE [CONTROLE ET MODIFICATION DE LA TURBULENCE]**

J. COUSTEIX, E. COUSTOLS, and D. ARNAL /in AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 34 p Apr. 1989 In FRENCH; ENGLISH summary Copyright Avail: NTIS HC A18/MF A01

Means devoted to control turbulence in boundary layers developing on aircraft are presented in order to reduce their skin friction drag. These means deal with the laminar flow control and the use of internal or external boundary layer manipulators. The description of the phenomena which are involved is given after recalling a few essential features of the transition process and of the turbulence in boundary layers. Author

**N90-10378\*** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.

**TURBULENCE MANAGEMENT: APPLICATION ASPECTS**

E. H. HIRSCHL, P. THIEDE (Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen, Germany, F.R.), and F. MONNOYER /in AGARD, Fluid Dynamics of Three-Dimensional Turbulent Shear Flows and Transition 12 p Apr. 1989

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Turbulence management for the reduction of turbulent friction drag is an important topic. Numerous research programs in this field have demonstrated that valuable net drag reduction is obtainable by techniques which do not involve substantial, expensive modifications or redesign of existing aircraft. Hence, large projects aiming at short term introduction of turbulence management technology into airline service are presently under development. The various points that have to be investigated for this purpose are presented. Both design and operational aspects are considered, the first dealing with optimizing of turbulence management techniques at operating conditions, and the latter defining the technical problems involved by application of turbulence management to in-service aircraft. The cooperative activities of Airbus Industrie and its partners are cited as an example. Author

**N90-10402\*** University of Southern California, Los Angeles. Dept. of Aerospace Engineering.

**DYNAMICS AND CONTROL OF TURBULENT SHEAR FLOWS**

Report, Oct. 1986 - May 1989

May 1989 61 p

(Contract N00014-86-K-0679)

(AD-A210396) Avail: NTIS HC A04/MF A01 CSCL 20/4

Topics of study during this time period include: Bounded Shear Flow - Experimental Approaches, Control of Laminar Separated Shear Layer on Airfoils; Control of Large Scale Features in Turbulent Mixing Layers; Direct Numerical Simulations of Flow Control; Control of Entrainment in Confined Shear Layers; Theoretical Underpinnings: Amplitude and Phase Descriptions of Coherent Structures; Phase Control of Vortex Structures in Shear Flows; Mathematical Analysis of Navier Stokes Equations; and Effects of Longitudinal Roughness Elements upon Turbulent Boundary Layer. Other areas of concern are: Some ideas on the Control of Near Wall Eddies; A technique for Acoustic Excitation of Separated Shear Flow; Heat Transfer in Rayleigh-Benard Convection; Energy Transfer and Non local Interactions in Homogeneous Isotropic Turbulence. Invariant Manifold Theory for Hydrodynamic transition; The theory of nonstationary viscous flow Past Plane Domains with Noncompact Boundaries; and Stability Properties of Subsonic Mixing Layers. GRA

**N90-10409\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**APPLICATION OF FORMAL OPTIMIZATION TECHNIQUES IN THERMAL/STRUCTURAL DESIGN OF A HEAT-PIPE-COOLED PANEL FOR A HYPERSONIC VEHICLE**

CHARLES J. CAMARDA and MICHAEL F. RILEY (PRC Kentron, Inc., Hampton, VA.) Oct. 1987 32 p

(NASA-TM-89131; L-16134; NAS 1.15:89131) Avail: NTIS HC

A03/MF A01 CSCL 20/4

Nonlinear mathematical programming methods are used to design a radiantly cooled and heat-pipe-cooled panel for a Mach 6.7 transport. The cooled portion of the panel is a hybrid heat-pipe/actively cooled design which uses heat pipes to transport the absorbed heat to the ends of the panel where it is removed by active cooling. The panels are optimized for minimum mass and to satisfy a set of heat-pipe, structural, geometric, and minimum-gage constraints. Two panel concepts are investigated: cylindrical heat pipes embedded in a honeycomb core and an integrated design which uses a web-core heat-pipe sandwich concept. The latter was lighter and resulted in a design which was less than 10 percent heavier than an all actively cooled concept. The heat-pipe concept, however, is redundant and can sustain a single-point failure, whereas the actively cooled concept cannot. An additional study was performed to determine the optimum number of coolant manifolds per panel for a minimum-mass design. Author

**N90-10424\*** Waugh Controls Corp., Chatsworth, CA.

**WIDE-RANGE FUEL FLOWMETER, PHASE 2 Final Report, 4**

Jun. 1986 - 3 Feb. 1988

WILLIAM SEILER, JR. Jul. 1989 120 p

(Contract F40600-86-C-0003)

(AD-A210547; AEDC-TR-89-6) Avail: NTIS HC A06/MF A01

CSCL 13/7

The Wide-Range Fuel Flowmeter (WRFF) development program proved the viability of the recirculation method of wide-range flow measurement over a 140 to 1 or greater range with a 1-percent or better measurement uncertainty. The objectives were to: (1) Reduce the size of the flowmeter and electronic conditioner and provide a more functional and economically producible system; (2) Replace the recirculating pump with a smaller, more reliable unit and assure that all components in contact with the fluid are compatible with jet fuels; (3) Provide means to disable recirculating flow when operating at high flow rates; and (4) Evaluate the performance of an air-driven pump for possible use in hazardous atmospheres. The meter was redesigned to greatly reduce its size and weight; large and expensive manifolds were eliminated, and wherever possible, commercially available



fittings were used. Inwardly pointing tubes were incorporated to inject and retrieve the recirculating flow, reducing recirculation flow variation and related recirculation flow errors. The electronic conditioner was repackaged in a standard 3-1/2-by 19-in. rack mount. An auto-zero feature was created and incorporated in the electronic conditioner, greatly simplifying the accelerating the zeroing process. GRA

**N90-10451\*#** MARC Analysis Research Corp., Palo Alto, CA. Finite Element Factory.

**THE MHOST FINITE ELEMENT PROGRAM: 3-D INELASTIC ANALYSIS METHODS FOR HOT SECTION COMPONENTS. VOLUME 3: SYSTEMS' MANUAL Final Report**

SHOHEI NAKAZAWA Jul. 1989 216 p  
(Contract NAS3-23697)

(NASA-CR-182236; NAS 1.26:182236; FEF/PD/1102/89-VOL-3)  
Avail: NTIS HC A10/MF A01 CSCL 20/11

The internal structure is discussed of the MHOST finite element program designed for 3-D inelastic analysis of gas turbine hot section components. The computer code is the first implementation of the mixed iterative solution strategy for improved efficiency and accuracy over the conventional finite element method. The control structure of the program is covered along with the data storage scheme and the memory allocation procedure and the file handling facilities including the read and/or write sequences. Author

**N90-10999#** Ingemansson Anatrol A.B., Askim (Sweden).

**VISCOELASTIC TUNED DAMPERS FOR CONTROL OF STRUCTURAL DYNAMICS**

WILLIAM G. HALVORSEN /in ESA, Spacecraft Structures and Mechanical Testing p 101-106 Jan. 1989  
Copyright Avail: NTIS HC A99/MF E06

The use of viscoelastic materials as the combined stiffness and damping element in the construction of tuned dampers is described. The variability of the dynamic mechanical properties of viscoelastic materials with environmental factors such as temperature, frequency, and dynamic strain amplitude lead to some difficulties in design and to possible instabilities in performance in certain applications. The effectiveness of tuned dampers is illustrated with an application for controlling low frequency fuselage response in a propeller aircraft. ESA

**N90-11245\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**LASER ANEMOMETER MEASUREMENTS IN A TRANSONIC AXIAL-FLOW FAN ROTOR**

ANTHONY J. STRAZISAR, JERRY R. WOOD, MICHAEL D. HATHAWAY, and KENNETH L. SUDER Washington Nov. 1989 216 p

(NASA-TP-2879; E-4480; NAS 1.60:2879) Avail: NTIS HC A10/MF A02 CSCL 20/4

Laser anemometer surveys were made of the 3-D flow field in NASA rotor 67, a low aspect ratio transonic axial-flow fan rotor. The test rotor has a tip relative Mach number of 1.38. The flowfield was surveyed at design speed at near peak efficiency and near stall operating conditions. Data is presented in the form of relative Mach number and relative flow angle distributions on surfaces of revolution at nine spanwise locations evenly spaced from hub to tip. At each spanwise location, data was acquired upstream, within, and downstream of the rotor. Aerodynamic performance measurements and detailed rotor blade and annulus geometry are also presented so that the experimental results can be used as a test case for 3-D turbomachinery flow analysis codes. Author

## 15

## MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

**A90-10483#**

**RISC LIFTING OFF IN AVIONICS**

JAMES M. H. WONG (Sanders Associates, Inc., Nashua, NH) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 45-51. refs (AIAA PAPER 89-2967) Copyright

The philosophy behind the use of the reduced instruction set computer (RISC) in avionics is addressed, and the merits of RISC versus the complex instruction set computer (CISC) are examined. The different RISC architectures are examined, using as illustrations the designs taken from various vendors. Cost aspects and technology trends are briefly considered. C.D.

**A90-10487#**

**USA - A SYSTEM TO REPRESENT AIRFOILS THROUGHOUT THE PRODUCT LIFE CYCLE**

LEON H. SEITELMAN and JEFFREY D. LANCASTER (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 76-81. (AIAA PAPER 89-2972) Copyright

This paper describes the Unified System for Airfoils (USA), a new system developed at Pratt and Whitney to guide the design of turbine and compressor airfoils. This system provides the engineering community with a dramatically enhanced capability to process the full range of airfoil geometries, by incorporating several key elements: a robust parametric cubic spline modeling capability, highly efficient utility routines for the mathematical operations that support the engineering tasks, labor-saving and user-friendly program organization and logical defaults, and complete documentation and tutorial support. The result of this effort is a system that correctly communicates the engineering design intent to manufacturing in minimum time and with maximum accuracy. Author

**A90-10529#**

**INTERACTIVE VIDEODISC TRAINING IN AEROSPACE APPLICATIONS**

KATHARINE GOLAS (Southwest Research Institute, San Antonio, TX) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 429-432. (AIAA PAPER 89-3029) Copyright

The main features of Interactive Videodisc (IVD) technology are reviewed with emphasis on applications to training in aerospace related tasks. With particular reference to IVD developed for training MH53-J helicopter aircrews in the use of the Combat Emergency Repair Kit, it is shown that IVD can provide realistic practice exercises without tying up expensive aircraft systems or simulators. The general content of the MH-53J IVD program is described. V.L.

**A90-10543#**

**A METHODOLOGY FOR MODELING, CONTROL DESIGN AND SIMULATION OF AEROSPACE MECHANICAL SYSTEMS**

VIKRAM N. SOHONI (Mechanical Dynamics, Inc., Ann Arbor, MI) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 523-526. refs (AIAA PAPER 89-3049) Copyright

## 15 MATHEMATICAL AND COMPUTER SCIENCES

This paper presents a technique for design and simulation of control systems applied to aerospace mechanical systems. Modeling of the mechanical and control system is performed using a large-displacement multibody dynamics software. The linear time invariant (LTI) representation of the mechanical system can be automatically extracted from this software and taken into any control design software to perform control design. To evaluate performance of the closed-loop feedback system, the control design is modeled along with the mechanical system model and simulated. This procedure is illustrated using an example. This methodology differs from the current procedures in the following two respects: (1) equations representing the model are created automatically from the physical model data; and (2) the LTI representation of the model can be obtained for the system at any suitable operating position. Author

**A90-10559#**

### **LINKING ARTIFICIAL INTELLIGENCE (AI) AND COMPUTER AIDED ENGINEERING (CAE) TO ANALYZE THE TESTABILITY OF ELECTRONIC DESIGNS**

STAN OFSTHUN (McDonnell Douglas Corp., Saint Louis, MO) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 679-685. (AIAA PAPER 89-3070) Copyright

The development of an automated tool which links AI and CAE to analyze the testability of proposed avionic designs in the early stages of the design process is discussed. It is maintained that the transfer of data between the CAE and AI software must rely on the use of the following standard data formats: the electronic design interchange format and VHSIC hardware description language. Constraints on automation are discussed with consideration given to data entry flexibility, dual perspectives, and modeling. A hybrid inferencing technique is described. K.K.

**A90-10567\*#** Stevens Inst. of Tech., Hoboken, NJ.

### **A METHODOLOGY FOR VALIDATING SOFTWARE RELIABILITY**

FREDERIC L. SWERN (Stevens Institute of Technology, Hoboken, NJ) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 742-748, refs

(Contract NAG1-587)

(AIAA PAPER 89-3081) Copyright

A significant problem associated with fault tolerant computer system design is how to insure that there are no embedded software errors, so that an avionics computer system meets the required reliability level. To accomplish this, it is necessary to associate a 'probability of failure' with the operational flight program. It would be more correct to say that the probability of excitation of existing latent design errors within the program is required. In this sense, latent software errors are like latent hardware faults, and techniques that were previously used to measure the probability of failure of hardware due to fault latency can be used to measure the probability of failure of the software. A methodology was developed and applied to a flight control program that was known to operate in a well defined environment. The results indicated that the technique could be used to provide a final validation of the software to a specified reliability level and to evaluate the role of flight test in software validation. Author

**A90-10568\*#** Charles River Analytics, Inc., Cambridge, MA.

### **AN EXPERIMENTAL INVESTIGATION OF FAULT TOLERANT SOFTWARE STRUCTURES IN AN AVIONICS APPLICATION**

ALPER K. CAGLAYAN (Charles River Analytics, Inc., Cambridge, MA) and DAVE E. ECKHARDT, JR. (NASA, Langley Research Center, Hampton, VA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 749-760, refs

(Contract NAS1-17705)

(AIAA PAPER 89-3082) Copyright

The objective of this experimental investigation is to compare the functional performance and software reliability of competing fault tolerant software structures utilizing software diversity. In this experiment, three versions of the redundancy management software for a skewed sensor array have been developed using three diverse failure detection and isolation algorithms and incorporated into various N-version, recovery block and hybrid software structures. The empirical results show that, for maximum functional performance improvement in the selected application domain, the results of diverse algorithms should be voted before being processed by multiple versions without enforced diversity. Results also suggest that when the reliability gain with an N-version structure is modest, recovery block structures are more feasible since higher reliability can be obtained using an acceptance check with a modest reliability. Author

**A90-10589#**

### **HIGH LEVEL LANGUAGE PROGRAMMING FOR AVIONIC VECTOR PROCESSORS**

KARL BROMMER (Analytix Electronic Systems, Hudson, NH) and TODD KLINE (U.S. Navy, Naval Air Development Center, Warminster, PA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 903-913, refs

(AIAA PAPER 89-3107) Copyright

The benefits and costs associated with programming vector processors in a high-level language are considered. The high-level language and microcode approaches are compared in terms of performance and complexity. The use of a vector-oriented language to generate code for noncompatible machines, including improvements to the current language to enhance its performance on the current U.S. Navy standard signal processor is discussed. K.K.

**A90-10590#**

### **A HETEROGENEOUS PARALLEL PROCESSING ARCHITECTURE FOR AVIONIC AND AEROSPACE APPLICATIONS**

J. DENNIS SEALS (AT&T Bell Laboratories, Whippany, NJ) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 914-919.

(AIAA PAPER 89-3108) Copyright

Future avionic and aerospace systems will require a diverse mix of signal, data, and decision processing at estimated throughput levels ranging from 0.1 to over 10 billion operations per second. Projections of the embedded software needed to support these systems range from 0.5 to over 10 million lines of code. AT&T Bell Laboratories has developed a heterogeneous multiprocessing architecture that will meet these processing requirements, and significantly reduce software development and support costs. The application support software augments the Ada toolset with a powerful graph language that functions as a program design language and in many cases is machine translatable into Ada code. A hybrid control mechanism provides a transparent interface between the application user and physical machine. The machine architecture is based on a modular building block concept and asynchronous communication network that permits processors with different functions, clock speeds, and data bandwidths to interact without incurring major protocol or data bottlenecks. Author

**A90-10599#**

### **A HARDWARE AND SOFTWARE FAULT TOLERANT SAFETY CONTROLLER**

HERBERT HECHT and MYRON HECHT (SoHaR, Inc., Beverly Hills, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 975-979, refs

(Contract DE-AC03-87ER-80532)

(AIAA PAPER 89-3123) Copyright

A safety controller for nuclear power applications that provides

hardware and software fault tolerance, immediate recovery from failures with diagnostics deferred until after recovery, and highly modular implementation is described. Potential applications to aircraft, launch vehicle, and spacecraft control systems are discussed. An extended distributed recovery block for a reactor control system is indicated schematically. K.K.

**A90-10600#****SOFTWARE FAULT TOLERANCE ANALYSIS AND TESTING FOR THE ADVANCED AUTOMATION SYSTEM**

D. A. FREVERT and R. D. DANCEY (IBM Corp., Rockville, MD) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 980-987. refs (AIAA PAPER 89-3124) Copyright

The Advanced Automation System (AAS) is a distributed real-time system under development for the FAA. The system is intended to replace the present en route and terminal approach ATC computer systems over the next decade. High availability in the presence of component failures, changes, and horizontal growth is an essential requirement for the system. This paper discusses the general approach to analyzing and testing the fault-tolerance capabilities of the AAS, by reviewing the approach used to identify failure modes in both commercial software products and project-unique code, and to verify that the system can recover rapidly in the presence of a wide range of errors. The reasons for selecting these techniques and the general methodologies used are discussed. Although the approach chosen takes into account factors unique to the AAS project, this approach to fault-tolerance analysis and testing can also be useful to others as a guideline for achieving effective system availability verification and growth. Author

**A90-10606#****GRAPHICAL INTERFACE TOOLS FOR AN AVIONICS SYSTEM**

MELANIE M. KHARRAZI (Boeing Advanced Systems, Seattle, WA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1034-1041.

(AIAA PAPER 89-3130) Copyright

Two tools were developed to aid the development and testing of a program called the Situation Assessor (SA), an avionics prototype subsystem that utilizes artificial intelligence techniques. The SA is written in LISP on a Symbolics workstation. It uses as input a knowledge base which contains objects in the form of trees. The scenario file which drives the SA was originally hand written in a LISP file, as was the knowledge base. It was desired that an end-user who might be knowledgeable in avionics threats and scenarios, but not necessarily in computer programming, might develop a knowledge base and scenario file for the SA. The threat editor and scenario editor were developed for this purpose and also as an aid in the development and testing of the SA. Author

**A90-10608#****THE AERODYNAMIC ASSISTANT**

D. J. PAISLEY (Boeing Helicopters, Philadelphia, PA), J. R. BLYSTONE, and G. R. WICHMANN (Boeing Computer Services, Seattle, WA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1052-1062. refs (AIAA PAPER 89-3132) Copyright

The development of the aerodynamic assistant to shorten the preliminary design cycle for aircraft from days to hours is described. This tool will provide rapid geometry feedback, expert advice, interfaces to detailed analysis tools, and a database management system to relieve the designer of data management chores. It is concluded that, through the use of a database management system for aircraft design, the problems associated with data redundancy between disciplines and the manual transfer of data between analysis applications are eliminated. K.K.

**A90-10614#****THE NIMBLE PROJECT - REAL-TIME COMMON LISP FOR EMBEDDED EXPERT SYSTEMS APPLICATIONS**

HENRY G. BAKER (Nimble Computer Corp., Encino, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1102-1107. refs

(Contract DE-AC03-88ER-80663)

(AIAA PAPER 89-3140) Copyright

Many significant expert systems for aerospace applications have been programmed in LISP - from a 'pilot's associate' to a system for the choice of targets in a European theater battle. The conversion of these and other expert systems for delivery to the field will require either reprogramming or recompilation using a much more sophisticated compiler than has hitherto been available for LISP. The NIMBLE Project is developing such a LISP compiler which is tuned for the compilation of expert systems written in LISP into a complete delivery system. This delivery compiler compiles complete applications - not just individual files - and allows for a degree of efficiency and safety which is impossible using a program development compiler. In addition, the NIMBLE LISP compiler produces highly portable code, since it can be instructed to output into C or Ada. Author

**A90-10615#****EMBEDDED KNOWLEDGE BASED AVIONICS**

GEORGE F. WILBER (Boeing Military Airplanes, Seattle, WA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1108-1113.

(AIAA PAPER 89-3141) Copyright

Artificial Intelligence knowledge-based programming provides reasoning and decision-making capabilities that are necessary for many advanced avionics systems which must perform intelligent real-time tasks. Existing knowledge-based systems generally do not function in real-time or in embedded environments. The embedded avionics environment provides some specialized characteristics that when exploited allow the development of efficient, real-time intelligent software. It is essential that the appropriate processor, programming language, and reasoning facilities are selected to provide real-time embedded performance and to allow efficient development, testing, and validation. Author

**A90-10616#****ADAPTING AN AI-BASED APPLICATION FROM ITS LISP ENVIRONMENT INTO A REAL-TIME EMBEDDED SYSTEM**

MIKE YEN (Boeing Advanced Systems, Seattle, WA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1114-1122. refs (AIAA PAPER 89-3142) Copyright

The development of a knowledge-based system prototype, the situation assessor (SA), as part of a smart avionics project is discussed. Particular attention is given to the experience gained from adapting the SA prototype from its LISP environment into a real-time embedded system by converting the SA program from LISP into Ada. Strategies for converting LISP to Ada are discussed with emphasis placed on the SA conversion strategy and a detailed mapping strategy (symbol manipulation, object-oriented design, set operations, the data length determined at runtime, heterogeneous data structure, and control structure). K.K.

**A90-10619#****ARTIFICIAL INTELLIGENCE TECHNIQUES APPLIED TO THE NON-COOPERATIVE IDENTIFICATION (NCID) PROBLEM**

ANNE K. BARRETTE (Northrop Corp., Aircraft Div., Hawthorne, CA), LAWRENCE C. JAMERSON (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH), and RICHARD A. ROGERS (Rogers Aerospace, Redondo Beach, CA) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5,

## 15 MATHEMATICAL AND COMPUTER SCIENCES

1989. 11 p. refs

(AIAA PAPER 89-3005) Copyright

Some techniques that can be applied to target identification are examined. In particular, attention is given to uncertainty management techniques (e.g., Bayesian, Dempster/Shafter, probabilistic, and fuzzy logic), temporal reasoning techniques, and iterative development and prototyping techniques using object oriented environments. It is shown that, of the techniques examined, Bayesian networks offer the best alternative for managing uncertainty within the friend/foe reasoning algorithms, while prototyping and refinement will allow fine-tuning of the Bayesian network. V.L.

### A90-10620#

#### INCORPORATION OF ALARM STATES INTO A REAL TIME DECISION MAKING PROCESS

ANDREW BORDEN (TRW, Inc., TRW Military Electronics and Avionics Div., San Antonio, TX) and JANET H. COOK (Perceptics Corp., Knoxville, TN) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989. 12 p.

(AIAA PAPER 89-3006) Copyright

A decision making process designed to be embedded in a Radar Warning Receiver (RWR) in a combat aircraft is described. An RWR uses some representation of a radar parametric data base and identifies emitters in the environment by comparing their parameters with those in the data base. An alternate methodology for handling potential alarm states when the emitters are first sensed by the RWR is described. The solution includes the development of alternative decision-making processes which are used when alarms occur. C.D.

### A90-10627#

#### APPLICATIONS OF NEURAL NETWORKS TO AVIONICS SYSTEMS

ABRAHAM N. SEIDMAN (Northrop Corp., Aircraft Div., Hawthorne, CA) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989. 11 p.

(AIAA PAPER 89-3093) Copyright

The application of neural networks is discussed as a method of solution to a number of outstanding problems in aircraft avionics. The areas of application of artificial neural networks to avionics dealt with are (1) target selection and (2) attack planning/steering. The target selection is approached by the application of a feed-forward, backpropagation network. The attack planning/steering is approached by a new type of parallel processing neural network. Author

### A90-10837

#### COMPUTER-AIDED DESIGN OF FLIGHT VEHICLE INSTRUMENT BAYS [AVTOMATIZIROVANNIA KOMPONOVKA PRIBORNYKH OTSEKOV LETATEL'NYKH APPARATOV]

VALERII N. GAVRILOV Moscow, Izdatel'stvo Mashinostroenie, 1988, 137 p. In Russian. refs

Copyright

Various aspects of software development for the computer-aided overall design of the instrument bays of flight vehicles are examined. In particular, attention is given to the functional and service requirements for the overall design of the instrument bay; computer-generated instrument bay models; implementation of the conditions of mutual nonintersection; and methods for solving general instrumentation layout problems. The discussion also covers algorithms for solving particular design problems related to instrument bay layout and the general structure and operation of a subsystem for the computer-aided design of instrument bays. V.L.

### A90-10844

#### ADAPTIVE AUTOMATIC CONTROL SYSTEMS. NUMBER 16 [ADAPTIVNYE SISTEMY AVTOMATICHESKOGO UPRAVLENIIA. NUMBER 16]

V. I. KOSTIUK, ED. Kiev, Izdatel'stvo Tekhnika, 1988, 160 p. In

Russian. For individual items see A90-10845 to A90-10848.

Copyright

The papers presented in this volume focus on the theoretical and application aspects of automatic control systems which adapt to changes in the operating conditions. Topics discussed include identification of the parameters of stochastic filtering processes; an analysis of the possibility of expanding the information base of an adaptive control system for a flight vehicle surrounded by an ionized gas medium; and structural and parametric identification of wave processes. Papers are also presented on the noise-immune Kalman filter for linearized systems; generalized structural and mathematical models of systems with elastic constraints; and a comparative analysis of adaptive robust estimation algorithms. V.L.

### A90-10848

#### THE DISCONTINUITY CONDITION IN THE OPTIMAL CONTROL PROBLEM FOR A COMPOSITE SYSTEM [USLOVIE SKACHKA V ZADACHE OPTIMAL'NOGO UPRAVLENIIA SOSTAVNYM OB'EKTOM]

A. I. LYSENKO IN: Adaptive automatic control systems. Number 16. Kiev, Izdatel'stvo Tekhnika, 1988, p. 136-141. In Russian. refs

Copyright

The optimal control problem for a composite system is analyzed with particular reference to the optimal control of multistage flight vehicles with separating stages. A procedure for the synthesis of optimal control for the transfer of the elements of a composite system from the initial manifold to a set of specified manifolds is presented. The approach described here can be used as the basis for developing the corresponding computational algorithm. V.L.

### A90-10963

#### FORMALIZATION AND SOLUTION OF COVERING PROBLEMS IN THE SYNTHESIS OF CONTROL AND MONITORING SYSTEMS [FORMALIZATSIIA I RESHENIE ODNOGO KLASSA ZADACH POKRYTIIA PRI SINTEZE SISTEM UPRAVLENIIA I KONTROLIA]

S. B. SHEKHOVTSOV and S. V. IAKOVLEV Avtomatika i Telemekhanika (ISSN 0005-2310), May 1989, p. 160-168. In Russian. refs

Copyright

A class of problems is considered which deals with the covering of a polyhedral set by polyhedron translations. The problems are formalized using linear inequality structures, and approaches to finding acceptable covering solutions are proposed. A solution to lattice covering problems is described for the case of fixed lattice angles. The class of problems considered here arises during the synthesis of control and monitoring systems at the stage of system structure selection. V.L.

### A90-11167#

#### THERMOSTRUCTURAL BEHAVIOR OF ELECTROMAGNETIC WINDOWS - ELABORATION OF A CODE PACKAGE

F. G. LATURELLE, E. C. HUGUES, and J. J. CASSAING (ONERA, Chatillon-sous-Bagneux, France) (European Electromagnetic Windows Conference, 5th, Antibes, France, Sept. 27-29, 1989) ONERA, TP no. 1989-145, 1989, 10 p. Research supported by DRET. refs

(ONERA, TP NO. 1989-145)

A code package, allowing the computation of the thermostructural response of electromagnetic or infrared windows during supersonic flights is described. It can deal with any shape and geometry and any thermophysical and mechanical behavior laws. It relies upon a modified version of the boundary layer code AERHET and the pre-processor QUICK, which allows the computation of aerodynamic heat loads, and on the finite element system ADINA, which allows the computation and display of temperatures and stresses. An axisymmetric, two-dimensional thermostructural analysis of a 60 mm radius nose of an imaginary missile accelerating from 1.8 to 3.8 Mach within 6 sec and decelerating to Mach = 2 within another 6 sec has been performed with no incidence and at 15,000 meter. The whole process

(aerothermal calculations, interpolation, data cards generation, thermal and mechanical calculations, post-processing) required about 30 minutes CPU time on a Celerity computer, while modeling and interpreting the results required much time. C.E.

**A90-12471**

**INVERSE PROBLEMS IN CONTROLLED SYSTEM DYNAMICS: NONLINEAR MODELS [OBRATNYE ZADACHI DINAMIKI UPRAVLIAEMYKH SISTEM: NELINEIYNE MODELI]**

PETR D. KRUT'KO Moscow, Izdatel'stvo Nauka, 1988, 328 p. In Russian. refs

Copyright

Based on the concepts of the inverse problems in control system dynamics, a theory is developed for the synthesis of motion control algorithms for nonlinear systems. The structure of the algorithms and their parameters are determined on the basis of the prescribed motion trajectories for the controlled systems. The theory developed here is used for solving a variety of applied problems, including problems concerned with the synthesis of control algorithms for robotic manipulators and aircraft. The dynamics of the synthesized systems is investigated, and the results of mathematical modeling are discussed. V.L.

**A90-12774**

**TIME DOMAIN PARAMETER IDENTIFICATION TECHNIQUES APPLIED TO THE UH-60A BLACK HAWK HELICOPTER**

D. A. TEARE, P. M. FITZSIMONS, B. H. TONGUE, and D. P. SCHRAGE (Georgia Institute of Technology, Atlanta) Vertica (ISSN 0360-5450), vol. 13, no. 3, 1989, p. 393-401. refs Copyright

The modeling and system identification of rotorcraft is described. The least squares and maximum likelihood methods are applied to flight test data from the UH-60A Black Hawk Helicopter. The trimmed flight conditions studied are forward flight at 100 knots and hover. Consideration is given to the derivation of helicopter equations of motion and the linearization of the equations of motion. K.K.

**N90-10586#** National Aerospace Lab., Tokyo (Japan).

**ON THE INTERACTIVE COMPUTER PROGRAM IPIS FOR AIRCRAFT PARAMETER IDENTIFICATION**

MASAHIKO NAGAYASU, SHUICHI SASA, and MASAOKI YANAGIHARA Oct. 1988 45 p In JAPANESE; ENGLISH summary

(NAL-TR-1000; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

A computer simulation program package, IPIS (Interactive Parameter Identification System), which was developed at the NAL for evaluation of flight test techniques concerning determination of aircraft performance characteristics from measured data in dynamic maneuvers, is described. The system is composed of programs for determination of parametric nonlinear aerodynamic model using wind tunnel test data, flight simulation, measurement simulation, motion reconstruction, identification of nonlinear aerodynamic models and calculation of performance characteristics. The system was evaluated using a simulation for the NAL STOL airplane. Author

**N90-10630#** National Aerospace Lab., Tokyo (Japan).

**GRID GENERATION PROCEDURE USING THE INTEGRAL EQUATION METHOD**

SUSUMU TAKANASHI Dec. 1988 12 p In JAPANESE; ENGLISH summary

(NAL-TR-1009; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

A grid generation method for arbitrary aircraft configurations, based on the singular integral equation for electrostatic fields, is presented. The electrostatic field can be visually represented by two families of lines, i.e., electrostatic potential and electrostatic force lines, which can also be utilized as one of the most promising computational grids. The singular integral equation is numerically solved by dividing the boundaries including body surface into a number of small triangular elements, as in the standard panel method. Typical examples obtained by the present method are also presented. Author

**N90-11487#** Integrated Systems, Inc., Palo Alto, CA.

**NONLINEAR MANEUVER AUTOPILOT FOR THE F-15 AIRCRAFT Final Report**

P. K. A. MENON, M. E. BADGETT, and R. A. WALKER Jun. 1989 90 p

(Contract NAS2-11877)

(NASA-CR-179442; H-1541; NAS 1.26:179442) Avail: NTIS HC A05/MF A01 CSCL 09/2

A methodology is described for the development of flight test trajectory control laws based on singular perturbation methodology and nonlinear dynamic modeling. The control design methodology is applied to a detailed nonlinear six degree-of-freedom simulation of the F-15 and results for a level accelerations, pushover/pullup maneuver, zoom and pushover maneuver, excess thrust windup turn, constant thrust windup turn, and a constant dynamic pressure/constant load factor trajectory are presented. Author

## 16

### PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

**A90-10169**

**INFRARED RADIATION MODEL FOR AIRCRAFT AND REENTRY VEHICLE**

K. BEIER (DLR, Institut fuer Optoelektronik, Wessling, Federal Republic of Germany) IN: Infrared technology XIV; Proceedings of the Meeting, San Diego, CA, Aug. 15-17, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 363-374. refs

Copyright

The NATO IR Air Target Model (Niratam), a computer model to predict the IR radiation of an aircraft in its natural surroundings, is described. The model accounts for the IR radiation from aerodynamically and internally heated surfaces, hot engine parts, combustion gas, and particles in the exhaust plume. The model calculates the reflected radiation of the sky and terrain background and the sun on the aircraft surface and determines the atmospheric transmission and emission between target and observer and the radiation of a homogenous background in the scene. Also, a reentry version of the model is described. Results are presented from the testing and validation of Niratam. R.B.

**A90-10229#**

**A STATISTICAL MODEL OF HELICOPTER NOISE [STATYSTYCZNY MODEL HALASU SMIGLOWCA]**

KATARZYNA DZIUBA, ZBIGNIEW CZERWINSKI, and ANDRZEJ CHYLA Instytut Lotnictwa, Prace (ISSN 0509-6669), no. 112-113, 1988, p. 75-107. In Polish. refs

The problem of the noise produced by modern helicopters is considered. On the basis of statistical data, three statistical models have been devised, to describe that noise. The formulas presented made it possible to predict, by statistical means, the real noise level for the three phases of flight, that is the take-off, the flight proper, and the landing. Those of the structural parameters of the helicopter, which are chiefly responsible for the noise, are also analyzed by statistical means. The results of the above considerations are used for identifying the main sources of noise. Author

**A90-11004#**

**SLIPSTREAM-INDUCED PRESSURE FLUCTUATIONS ON A WING PANEL**

STEN LJUNGGREN, INGEMAR SAMUELSSON, and KURT WIDIG (Flygtekniska Forsoksanstalten, Bromma, Sweden) Journal of Aircraft (ISSN 0021-8669), vol. 26, Oct. 1989, p. 914-919. refs Copyright

Propeller-induced pressure fluctuations have been measured on a wind-tunnel model. The results show that the main contribution on the wing panels can be attributed to the propeller tip vortex, which gives a pressure level at least 20 dB above the level from the inner parts of the propeller. The pressure fluctuations are predominantly periodic and the spectrum shows strong peaks at the blade passage frequency and its harmonics. The pressure level at the blade passage frequency is approximately the same on wing panel and fuselage, while the level of the higher harmonics is substantially higher on the wing panel than on the fuselage.

Author

#### A90-11027

##### HIGH PERFORMANCE SINGLE-MODE COUPLER FOR HARSH ENVIRONMENTS

ARUN AGARWAL and PAUL RIVETT (Canada Wire and Cable, Ltd., Canstar Div., North York) IN: Components for fiber optic applications III and coherent lightwave communications; Proceedings of the Meeting, Boston, MA, Sept. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 11-17.

Copyright

The paper reports the development of a high-performance ruggedized single-mode coupler for an operating temperature range of -55 C to +125 C. Test couplers have been subjected to environmental tests recommended for air-borne fiber-optic components for use in data buses in commercial and military aircraft. The design features of the coupler is reported, as well as its optical performance characteristics and environmental test results.

Author

#### A90-11666

##### AN ANALYSIS OF RELIABILITY IN FIBER OPTIC RING AND STAR NETWORKS

W. A. ROSEN, S. M. SMITH (U.S. Navy, Naval Air Development Center, Warminster, PA), and C. SCHRAGER (Keystone Computer Associates, Fort Washington, PA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 49-56.

Copyright

Four high speed optical data bus topologies suitable for avionics applications have been analyzed for system reliability. Counter-rotating rings, redundant parallel rings, and redundant passive and active star networks were modeled by a Monte Carlo simulation in which random failures were assigned to optical links, passive bypasses, and stations according to preselected probabilities. The results of the analysis indicate that, of the two ring systems, the counter-rotating ring was less reliable except in the limit of high link reliability and poor station reliability. This suggests that, in the case of avionic systems, where connectors often represent a significant failure mode, counter-rotating rings will be less reliable. It is also found that techniques for bypassing large numbers of failed stations will not significantly improve ring reliability. Both passive and active stars proved to be more reliable than either ring network, suggesting that a star may be the topology of choice, even in the case of a very large network.

Author

#### A90-11801#

##### THE ACOUSTIC PHENOMENA OF THE STALLING FLUTTER

Z. A. HU, Y. C. FENG, X. H. ZHAO, and Y. W. WANG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 657-662. refs

An experimental study and measurement analysis is conducted of 275-285 Hz acoustic phenomena associated with the stalling flutter of an axial-flow rotor which has been designed to yield zero total aerodynamic damping at the stall-flutter onset. The two different blade-tip clearances used are 1.6 and 0.5 mm. The

multiple-circular arc airfoils employed by the rotor blades are found to possess poorer aeroelastic stability than those of double-circular arc design. The smaller tip clearance is found to result in poorer aeroelastic stability than the larger one.

O.C.

#### A90-11803#

ACOUSTIC RESONANCE IN CENTRIFUGAL COMPRESSORS INDUCED BY INTERACTION BETWEEN ROTOR AND STATOR V. B. KURZIN, R. A. IZMAILOV, and V. L. OKULOV (AN SSSR, Institut Gidrodinamiki, Novosibirsk, USSR) IN: Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium, Aachen, Federal Republic of Germany, Sept. 6-10, 1987. Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, p. 677-688. refs

An experimental investigation is conducted of acoustic resonance phenomena generated in centrifugal compressors by the interaction between rotor and stator, with a view to the theoretical characterization of the conditions under which the excitation of resonance occurs. The theoretical model used assumes that the velocity of a basic stationary airflow representing the spiral flow is comparatively low, that the airfoils in question are thin, and that the sources of acoustic disturbances are absent outside the outer cascade radius. Good agreement is obtained between computational and experimental results.

O.C.

#### A90-11878

##### TWENTY-FIVE YEARS OF ROTORCRAFT AEROACOUSTICS - HISTORICAL PROSPECTIVE AND IMPORTANT ISSUES

J. W. LEVERTON (E. H. Industries, Inc., Arlington, VA) Journal of Sound and Vibration (ISSN 0022-460X), vol. 133, Sept. 8, 1989, p. 261-287. refs

Copyright

Developments over the past 25 years in the area of predicting and understanding the 'helicopter noise' associated with turbine-powered rotorcraft are discussed. Particular consideration is given to the importance of the recording/analysis systems in the collection of data, the rotor noise mechanisms, the aeroacoustic theory, the theory of high-frequency rotational noise, the experiments on broadband noise and the theory of it, and studies on blade slap, blade-vortex interaction, thickness noise, and the main rotor wake-tail rotor interaction. It is concluded that, while considerable advancements were made in the acoustic theories, the overall prediction of helicopter noise is still relatively poor, and, for a number of years to come, is likely to be a combination of empirical and theoretical predictions.

I.S.

#### A90-11884

##### APPLICATION OF LOCALIZED ACTIVE CONTROL TO REDUCE PROPELLER NOISE TRANSMITTED THROUGH FUSELAGE SURFACE

M. SALIKUDDIN and K. K. AHUJA (Lockheed Aeronautical Systems Co., Marietta, GA) Journal of Sound and Vibration (ISSN 0022-460X), vol. 133, Sept. 22, 1989, p. 467-481. refs

Copyright

An innovative concept of 'localized active noise control' is experimentally demonstrated in achieving a satisfactory cabin noise reduction for propeller aircraft. The principle of localized active noise control is to reduce the propeller noise (primary source) only locally in the vicinity of an antiphase sound source (secondary source) which is mounted on the wall of an aircraft cabin. Then, several such sound sources mounted on the cabin wall can reduce the propeller noise over a large area on the cabin surface and behind it. This has been demonstrated by conducting a laboratory experiment in which an acoustic driver generating discrete frequency sound behind a thin metallic surface was used as the primary source. Four other acoustic drivers mounted on the surface were used to generate the antiphase sound on the other side of the surface. The measured noise field behind the metallic surface indicates satisfactory noise reduction. The present experimental arrangement works particularly well at low frequencies, but more secondary sources will be required for high-frequency noise. Another potential application of this technique, demonstrated in



this paper, is to reduce noise levels in selected areas on the exterior of the aircraft where sonic fatigue may be critical.

Author

**N90-10679\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**MEASUREMENT RESOLUTION OF NOISE DIRECTIVITY PATTERNS FROM ACOUSTIC FLIGHT TESTS**

DAVID A. CONNER Washington Oct. 1989 43 p  
(NASA-TM-4134; L-16456; NAS 1.15:4134;  
AVSCOM-TR-89-B-004) Avail: NTIS HC A03/MF A01 CSCI 20/1

The measurement resolution of noise directivity patterns from acoustic flight tests was investigated. Directivity angle resolution is affected by the data reduction parameters, the aircraft velocity and flyover altitude, and by deviations of the aircraft from the desired flight path. Equations are developed which determine bounds for the lateral and longitudinal directivity angle resolution as a function of the nominal directivity angle. The equations are applied to a flight test data base and the effects of several flight conditions and data reduction parameters on the directivity angle resolution are presented. The maximum directivity angle resolution typically occurs when the aircraft is at or near the overhead position. In general, directivity angle resolution improves with decreasing velocity, increasing altitude, increasing sampling rate, decreasing block size, and decreasing block averages. Deviations from the desired ideal flight path will increase the resolution. For the flight experiment considered in this study, an average of two flyovers were required at each test condition to obtain an acceptable flight path. The ability of the pilot to maintain the flight track improved with decreasing altitude, decreasing velocity, and practice. Due to the prevailing wind conditions, yaw angles of as much as 20 deg were required to maintain the desired flight path.

Author

**N90-10683\*#** Hamilton Standard, Windsor Locks, CT.  
**ACOUSTIC TEST AND ANALYSIS OF A COUNTERROTATING PROP-FAN MODEL Final Report**

BERNARD MAGLIOZZI, PAUL BROWN, and DAVID PARZYCH Oct. 1987 156 p  
(Contract NAS3-24222)  
(NASA-CR-179590; NAS 1.26:179590) Avail: NTIS HC A08/MF A01 CSCI 20/1

Results of acoustic tests of a 62.2 cm (24.5 in) diameter model counterrotating Prop-Fan are presented. The model was tested as a tractor and a pusher downstream of a pylon, both at 0 degrees and at 4 degrees angle-of-attack. The effects on noise of spacing between rotors and between the pylons and the rotors were also measured. Effects of rotor spacing were found to cause small changes in noise over the range of spacings tested. The presence of the pylon resulted in a 2 to 3 EPNdB increase in noise. Angle-of-attack effects showed an increase of 3 to 4 EPNdB for the tractor and only about 1 EPNdB for the pusher configuration. Speed was found to be the strongest parameter in minimizing noise. However, the decrease in noise with tip speeds below 200 m/sec (650 ft/sec) became significantly smaller than at higher tip speeds. Comparison of noise spectra between single rotation and counterrotating Prop-Fans showed that the counterrotating Prop-Fan has significantly higher levels of higher frequency noise which radiates in the forward direction. Correlations between measurement and prediction are discussed. Predictions are made of far-field noise during takeoff and near-field noise during cruise.

Author

**N90-11549\*#** General Electric Co., Cincinnati, OH. Advanced Engineering Technologies Dept.

**AN INVESTIGATION OF COUNTERROTATING TIP VORTEX INTERACTION**

R. K. MAJJIGI, K. UENISHI, and P. R. GLIEBE Oct. 1989 124 p  
(Contract NAS3-24080)  
(NASA-CR-185135; NAS 1.26:185135) Avail: NTIS HC A06/MF A01 CSCI 20/1

A tip vortex interaction model originally developed for

compressors has been extended and adapted for use with counterrotating open rotors. Comparison of available acoustic data with predictions (made with and without the tip vortex model included) illustrate the importance of this interaction effect. This report documents the analytical modeling, a limited experimental verification, and certain key parametric studies pertaining to the tip vortex as a noise source mechanism for the unsteady loading noise of counterrotating propellers.

Author

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### SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

#### A90-11393

##### RECENT CASES AND DEVELOPMENTS IN AVIATION LAW

JAMES F. STIVEN (California, University, Los Angeles) Journal of Air Law and Commerce (ISSN 0021-8642), vol. 55, Fall 1989, p. 1-121. refs  
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Consideration is given to jurisdiction for aircraft cases, product liability claims, the federal tort claims act, contribution and indemnity, and insurance coverage. Topics related to premises liability, preemption, jurisdiction, equal protection, and free speech in airports; landing and terminal rental fees; noise abatement; and auto concessions are discussed. The Warsaw Convention is examined in terms of jurisdiction, injuries, cargo and passenger baggage claims, statute of limitations, and damages. Limitations of actions; negligence; antitrust; and FAA enforcement, local regulations, and administrative law are also discussed. I.F.

#### A90-11396

##### PLACARDS, WARNING LABELS AND OPERATION MANUALS - AN AIRCRAFT MANUFACTURER'S DUTY TO WARN

JAMES E. LINK, II Journal of Air Law and Commerce (ISSN 0021-8642), vol. 55, Fall 1989, p. 265-302. refs  
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The effectiveness of aircraft warnings is studied. Basic warning claims and their influence on manufacturers are discussed. Actual and proposed safety warnings are analyzed in terms of case law in this area. Human factor psychology and engineering are considered; particular attention is given to the limitations of traditional tort law in terms of warnings and instructions. I.F.

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#### A90-12478

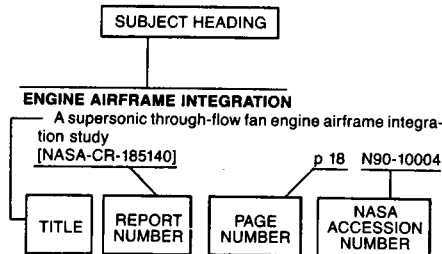
##### THE BIRTH OF THE AIRPLANE: THE FIRST DESIGNS AND CONSTRUCTIONS [ROZHDENIE SAMOLETA: Pervye Proekty i Konstruktsii]

DMITRII A. SOBOLEV Moscow, Izdatel'stvo Mashinostroenie, 1988, 208 p. In Russian. refs  
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Information on the first airplane and glider designs (before 1914) is presented. The developments are given chronologically and illustrated by drawings. B.J.



## Typical Subject Index Listing



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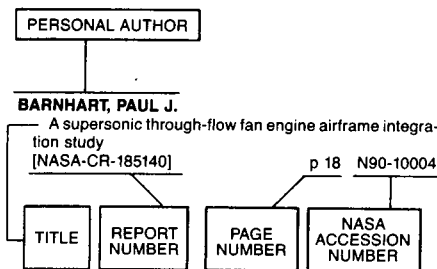
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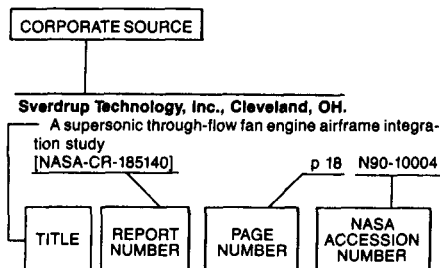


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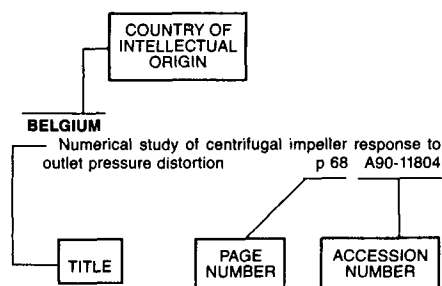
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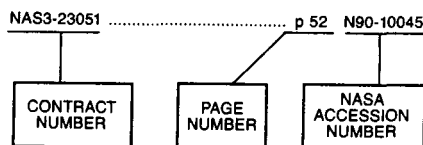


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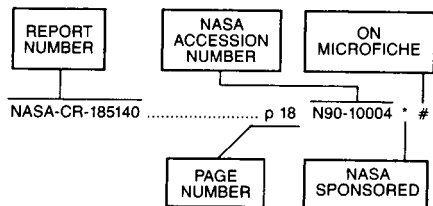
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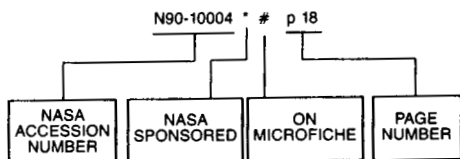
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